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The Effect of Wind-Current on Rainfall.*

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The value of rainfall observations for the purpose of meteorology, climatology, and agriculture, depends upon the degree of approximation with which they represent the average rainfall over a considerable area. A single gauge can measure only the rain actually falling within its circumference, but, on the assumption that the amount collected by the gauge is a true measure of the precipitation, and that the distribution of rainfall is uniform, its records are taken as the average rainfall over the surrounding district. It is important, then, to know how far these conditions are realized, and how nearly the assumptions are justified.

As a matter of fact, the topography of the country, the position of the gauge with respect to buildings, and the direction of the wind, produce large variations in the amount of rainfall collected, and it is evident that the more local the disturbing influence the more restricted will be the significance which we can attach to the rainfall observations. It is desirable, then, to institute special comparative observations at as many stations as possible, for the purpose of ascertaining: 1st, the effect of local influences: 2d, the uniformity of rainfall over a considerable area; and 3d, the degree with which the records of a given position approximate to the average—thus determining completely the significance of the observations of a single gauge. The variation of rainfall of a gauge in any location, from the general average of many gauges in all positions, may thus be approximated, and, either a corresponding correction applied, or the record given a weight dependent on the value of the observations.

As an aid to such investigations it is the object of this paper to present: 1st, a brief historical summary of our present knowledge of the variations produced by wind in the *collection* of rain: 2d, some of the results of observations in different countries, showing the variations produced by wind in the *distribution* of rain; 3d, the results of special rainfall observations made at the Signal Service station on the summit of Mount Washington, New Hampshire.

During the past fifty years the whole subject of rain collection has been investigated principally in connection with the question of the variation of the amount of rainfall at different elevations, in explaining which the most widely different theories have been proposed. It is only within the past few years that a final conclusion has been reached and the question, apparently settled. In the last century (1766) it was observed by Doctor Heberden that rain-gauges placed on the ground collect, in general, a larger amount of rain than gauges on roofs and towers. In lack of any satisfactory explanation of this variation, Doctor Heberden says: "It is probable that some hitherto unknown property of electricity is concerned in this phenomenon." Some years later, Benjamin Franklin, then in England, suggested that the increase of rain collected in gauges on the ground might be due to the augmentation of the rain drops by the condensation of moisture on their surfaces during their fall. Though this hypothesis was considered by Doctor Franklin himself to be inadequate and open to objection, it became, in later years, the generally accepted explanation of the phenomenon. The subject continued to attract occasional attention both in England and on the continent,† but no decisive or generally accepted conclusion was arrived at.

In 1832, at the suggestion of the British Association and with a grant of money for the purpose, systematic observations were undertaken. As the result, Prof. John Phillips, who conducted the experiments, advanced as an explanation the same hypothesis that was suggested by Franklin in 1771, namely, "the whole difference in the quantity of rain at different heights above the surface of the ground is caused by the continual augmentation of each drop of rain from the commencement to the end of its descent, as it traverses successively the humid strata of air at a temperature so much lower than that of the surrounding medium as to cause the deposition of moisture upon its surface."

That this theory is entirely inadequate to explain the phenomena was shown by Sir John Herschel, who demonstrated, mathematically, that the increase of a raindrop within the last few hundred feet of descent must be absolutely inappreciable.‡

The first step towards a true explanation, supported by the results of observation, was made by Prof. A. D. Bache, of Philadelphia, in a report in 1837, to the British Association, entitled: "Note on the effect of deflected currents of air on the quantity of rain collected by a rain-gauge."

Prof. Bache made the important discovery that of four gauges placed at the corners of a roof, in general, the gauges to leeward received more rain than those to windward. From this discrepancy he was led to the belief that the effect of eddy-winds is a fact of primary consideration in the whole question of rain-gauge exposure.

No further advance of importance seems to have been made till 1861, when a complete theoretical explanation of the action of the wind in producing variations in observed rain-fall was presented by W. Stanley Jevons in the Philosophical Magazine.

The importance of this memoir justifies us in making the following extract:

"A stream of air, then, meeting an obstacle leaps over it; in so doing it is forced against the adjoining parallel stream of air, which must also diverge from the straight direction and similarly impinge upon the next stream.

"But the increased pressure, produced by the impact, causes the streams of air to move more rapidly and to diminish in thickness at the same time; and the disturbance of the streams of air will cease at the point where the total decrease of size of the streams is equal to the height of the obstacle.

"It is at least obvious that when a uniform wind meets an obstacle some parts of the air must move more rapidly, just as a river moves most rapidly in the narrowest parts of its channel.

"It is quite in accordance, too, with our common experience that an obstacle increases the velocity and force of the wind; thus, the wind is always most fierce at the corner of a house, the end of a wall, or the summit of a hill.

"We have now the whole explanation of the rain observations in question. A drop of rain in falling is influenced at once by gravity and the motion of the air. It describes the diagonal of a rectangle of which the perpendicular side represents the falling velocity of the drop, and the horizontal side the velocity communicated by the wind.

"Now conceive two equal drops of rain falling into a current of air at points where the velocity is not the same. They will not pursue parallel paths, but the one drop will either approach to or recede from the other. The effect will be to increase or diminish the quantity of rain falling in the intermediate space.

"To show clearly the nature of this effect we may imagine the stream of air *M N* (Fig. 1) to be suddenly contracted at *B C* to half its previous thickness, so, that of course, it must there commence to move with double velocity. At *A D* the stream dilates to its original size, and of course recovers its first velocity. The course of of equi-distant rain drop falling into wind under such imaginary circumstances would be represented by the oblique lines, and it is obvious that less rain would fall in the windward part of the contracted space than elsewhere.

"To represent a real shower of rain falling upon an obstacle, we have only to conceive the drops of rain as falling through a great number of strata, all varying in velocity and thickness."

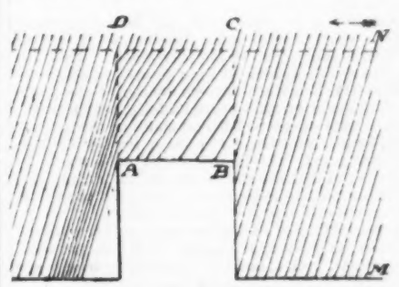

FIG. 1.

In view of the results of this memoir by Jevons the subsequent history of the problem, as represented by discussions in "British Rainfall" and the "Meteorological Magazine," during the next twenty years, is a most remarkable instance of neglect to profit by earlier investigations.

In an article in "British Rainfall" for 1866, the whole question is re-opened, and the reader is left at sea with the cheering information that "if we are still in doubt as to the *cause* of the decrease with elevation, we are no longer in much uncertainty as to its *amount*." In 1871, in the same publication, Rev. F. W. Stowe, in a valuable article, showed graphically the influence of buildings in diverting rainfall during the prevalence of non-horizontal wind currents.

Comparative observations were now begun on an extensive scale. As the result of these Mr. G. Dines presented (see "British Rainfall," 1877) conclusion *almost identical* with those of Bache in 1838, and of Jevons in 1861, and in a re-discussion of the observations, by Rogers Field (see "Meteorological Magazine," 1878, vol. xiii.), additional confirmation was given in greater detail.

In the same year Symons recapitulated the discussion and published in full the article of Bache, which had been suffered to fall into oblivion. In a summary he says:

"The terribly hard-fought battle, respecting the reason that a smaller quantity of rain is collected by rain-gauges elevated above the surface of the ground, is nearly settled, for the following points seem proved:

"The greater part of the decrease is due to wind.

"The stronger the wind, the greater the decrease with elevation.

"The less the diameter of the elevated gauge, the less will it indicate.

"A gauge on the leeward side of a tower may collect as much rain as one on the ground.

"A gauge in the middle of a large roof may, notwithstanding its height, collect very nearly the same as one upon the ground."

In the following year, after a study of all available observations, Symons further concludes that "there is no evidence of any difference between the fall of rain at various heights from sixty feet to two hundred and sixty feet above the ground."

The last paper, a report by Symons to the British Association in 1881, reviews the discussion and concludes by saying that all recent investigations only confirm the results obtained by Bache and Jevons, with a few additional points that could have been directly inferred from their work.

In the investigation of the difference in rainfall with elevation above the ground the influence of buildings and the action of wind-currents have thus been ascertained, and the best exposure of gauges to secure average results has been determined.

In a résumé of the literature of this question, mention should also be made of an hypothesis first advanced by Prof. Phillips and again presented by Mr. Dalmahoy in 1862 (Trans. Roy. Soc., Edinburgh, vol.

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* Signal Service notes, No. XVI, 1884.

† Among others, see articles by—
Flaugergues, Bibl. Univ., VIII., 1818, p. 127; Annals of Phil., XIV., 1819, p. 113.
Meikle, Annals of Phil., XIV., 1819, p. 212.
Bosse, H. Annals of Phil., N. S., Iv., 1822, p. 19.
Arago, Ann. Chim. et Phys. XVIII., 1821, p. 410; XXVII., 1824, p. 309; Poggend. Annal., XXIII., 1834, p. 417.

‡ See article on Meteorology, Enc. Brit., 8th Ed.

xxiii.,) in which the decrease of rainfall with elevation is supposed to be due to the effect of downward currents of air that are set in motion by the falling raindrops. This ingeniously elaborated hypothesis was advanced because of the supposed inadequacy of the theory of eddy winds to explain the difference that Phillips and Arago reported to exist in times of calm, as well as the difficulty that, of three gauges at three different levels, the lowest gauge always receives more rain than the middle one, and the middle gauge more than the upper. Both these conditions seem to be shown, by the later investigations above quoted, not to exist, and, consequently, Mr. Dalmahoy's downward currents are not needed to account for the observed differences.

Numerous contributions to this subject have also been made by French meteorologists, of which the most noteworthy since the time of Arago are those of E. Renou.* In a communication to the Meteorological Society in 1863 he pointed out that the difference in the amount of rainfall collected at different heights depends not only upon the velocity of the wind but also upon the size of the drops. Large drops are less easily deflected by wind currents than small ones, and consequently give less variation in the amount of rain collected by different gauges.

We now come to the second and larger question, namely: What variation in the distribution of rainfall due to wind is produced by the *topography* of the country? The practical problems have already been stated, namely: (1) to find over what area the record of a single gauge gives the average precipitation; and (2) to determine, from gauges at different stations, the precipitation, for any other locality to which the law applies, can be computed. This is practicable only for those countries and districts where the rainfall, being dependent on regular and constant winds, the variations in precipitation are progressive and uniform.

The desirability of such determinations for southern India is pointed out by J. Allan Broun in "Trevandrum Observations," vol. i., and the following problems are specified as desirable matters of investigation:

1st. The law of rainfall along the coast, which diminishes from Cochin to Cape Comorin; 2d, the variation of the fall proceeding from the coast towards the mountains; and 3d, the variation with height on the Ghats with reference to coffee and other cultivation.

With these laws determined, Mr. Broun believed the number of stations in the district might be reduced to eight.

Among the effects of the topography of the country on the distribution of rainfall the variations in mountain districts are especially noticeable, and it is to these we shall confine our attention. In general, the amount of rain increases with the elevation above sea-level up to a maximum plane, after which a decrease takes place. S. A. Hill has shown (see "Zeitschrift für Meteorologie," vol. xiv., 1879) that in the northwest Himalayas, where the rainfall is most remarkable in amount and rate of variation, the observations can be represented by the following empirical formula:

$$R\,(\text{amount of rain}) = 1 + 1.92h - 0.40h^2 + 0.02h^3$$

in which h is the relative height in units of 1,000 feet above an assumed plane which is itself 1,000 feet above sea-level. From this formula the height of maximum rainfall is computed to be 3,160 feet above the plane, or 4,160 feet above sea-level. It is further shown that this elevation is that at which, according to the observed law of decrease of temperature, the southwest monsoon is cooled just below its dew-point. This point will be that at which, in the mean, we should expect the maximum precipitation to take place. The results obtained from the empirical formula thus receives a theoretical and deductive confirmation. In the following volume of the "Zeitschrift" (vol. xv., 1880, p. 373,) Hann has collected observations from stations on the Arlberg, in the western Tyrol, by which the plane of maximum rainfall is shown to be at a somewhat higher level in that region than in India. The highest station, at an elevation of 5,900 feet, has the maximum rainfall. A very rapid diminution takes place on the leeward side, where the stations record only about half the amount of rainfall given by stations of equal altitude on the windward side.

The "Report upon the Rainfall of Barbados," by Governor Rawson, giving the results of observations from 1847 to 1871, shows a similar variation with altitude; the amount of rain increases regularly with the height of station except in a few localities where the law is masked by other local causes of variation.

*Renou, E.—Sur les quantités de pluie recues par deux pluviometrés différant de hauteur ou de dimensions. Ann. Soc. Mét. de France vol. xi., 1863, pp. 69-73; Sur les quantités d' pluie recueillies a deux niveaux différents; *idem*, vol. xiii., 1865, pp. 162-163; vol. xxvii., 1879, p. 109.

Haeghens, J.—Sur les observations pluviométriques faites a deux niveaux différents pendant 32 années consécutives, de 1817 a 1848. Ann. Mét de France, vol. iii., 1851, pp. 155-158.

Goulier, C. M.—Influence de la position d'un pluviométre sur la quantité de pluie qu'il indique. Bull. Inter. del'Observatoire de Paris, April, 1864.

Dausse—Sur les quantités de pluies recues par pluviométres a des hauteurs différentes. Ann. Soc. Mét. de France, xxvii., 1879, pp. 89-92.

Maille, P. H.—Nouvelle théorie des hydrométéores, p. 278. Paris, 1853.

Paris, Service hydrométrique, Manuel hydrologique du bassin de la Seine, Paris, 1884.

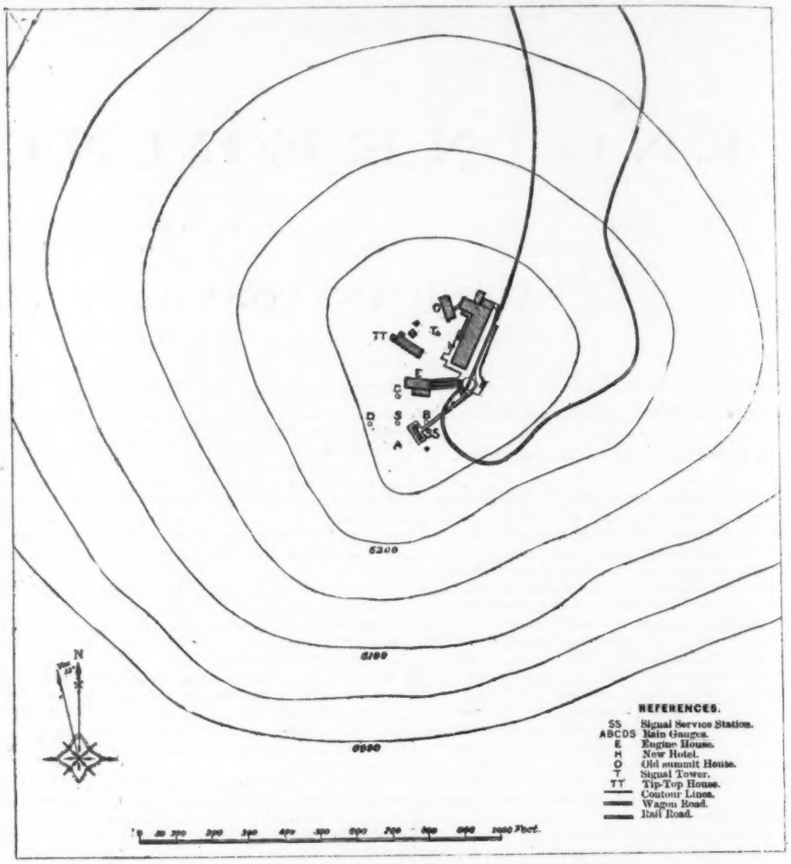

PLATE I.—MAP OF THE SUMMIT OF MT. WASHINGTON.

The explanations offered for this increase of rainfall with altitude above sea level have been as various and as ingenious as those for the decrease of rainfall on towers and buildings, reviewed in the first part of this paper. The first explanation offered was designed especially to account for the rains on the Himalayas, and was to the effect that a certain stratum of the southwest monsoon contains a greater quantity of moisture than the other strata and therefore gives a maximum precipitation. This hypothesis was rendered untenable by the actual observations of Hooker and Strachey, which showed a steady diminution of vapor-tension with increase of altitude. A discussion of these observations by Strachey (Proceedings of the Royal Society, March, 1861,) together with a later investigation by Hann ("Zeitschrift für Meteorologie," vol. ix., 1874,) who derives a formula for the decrease of vapor with altitude, have greatly increased our knowledge as to the distribution of aqueous vapor in the upper parts of the atmosphere.

A second explanation was that the contact of the moist air with the cold surface on the ground, on mountain sides and hill tops, produces the increased precipitation. In answer to this supposition it may be said that only the air within a short distance of the ground is cooled in this manner. But, as it has been already shown that the lower strata of the air give no appreciable rainfall, this hypothesis is inadequate to explain the increase that must be accounted for. Other similarly insufficient explanations, such as that of the mixing of warm and cold air, have been advanced.

The real cause is undoubtedly to be found in the cooling of air by expansion, whereby vapor-laden windcurrents, forced to ascend mountains or elevated plateaus, expand against surrounding atmospheric pressure and are cooled below the dew-point, so that their moisture is precipitated. This principle explains the fact, already mentioned, that the plane of maximum rainfall in the northwest Himalayas is that at which, by the law of diminishing temperature, an ascending current of vapor would be cooled down to the dew-point, whereupon precipitation must ensue.

The preceding examples of the variations of rainfall on mountain slopes in India, Europe, and the West Indies, with the individually varying results that have been found, show the necessity of numerous comparative observations in all mountainous districts if we expect to obtain any accurate knowledge of rainfall distribution.

The large rainfall recorded at the Signal Service station on the summit of Mount Washington has seemed particularly worthy of careful study, and special observations have been undertaken. The first point of investigation has been relative to the distribution of rain on the summit itself, since it seemed probable that the enormous wind velocity experienced there might produce sensible inequalities, both in the gauge readings and in the actual rainfall, wherefore the records of a single gauge would not present average results for the whole summit.

From September 1, 1882, to October 1, 1883, comparative observations were made daily with four extra gauges, placed seventy-five feet north, south, east, and west of the station gauge (see map of summit, Plate I.) These gauges were cylindrical, fourteen inches deep, and surmounted by a small receiving cup, three inches in diameter.

As the observer reported that the measurement of snow is altogether unreliable for comparative purposes owing to the velocity of the wind, the observations used in the following discussion will be those of rainfall only. The result of this series of observations is given in the following Table, I., containing the rainfall only during the thirteen months of observation; the records of each gauge are first tabulated according to the direction of the wind.

TABLE I.—*Rainfall, excluding snow, September, 1882—September, 1883, inclusive on Mount Washington.*

	A	B	C	D
NE.	1.48	1.31	1.47	1.43
E.	18	15	18	16
SE.	1.24	2.60	1.87	1.65
S.	4.33	8.28	6.91	6.40
SW.	3.29	4.20	3.85	3.71
W.	4.92	5.13	4.02	3.70
NW.	29.15	28.23	26.31	24.93
N.	1.23	1.20	0.79	0.65
Total	45.82	51.19	45.40	42.63

Location of extra gauges: A, 75 feet south of station gauge; B, 75 feet east of station gauge; C, 75 feet north of station gauge; D, 75 feet west of station gauge.

This table exhibits discrepancies in the total amounts of rain collected in the several gauges, apparently too large to be attributed to errors in collection and measurement. The first result obtained from the observations is, then, that the *precipitation varies materially within distances of only one or two hundred feet.*

The law of the variation is next to be sought for. By arranging the figures of the preceding table according to the relative location of the gauges to windward or leeward, as in the following table, the law of variation is rendered apparent.

It will be seen that with a few exceptions, to be noted hereafter, the windward gauges record the least rain, the central gauges somewhat more, and the leeward

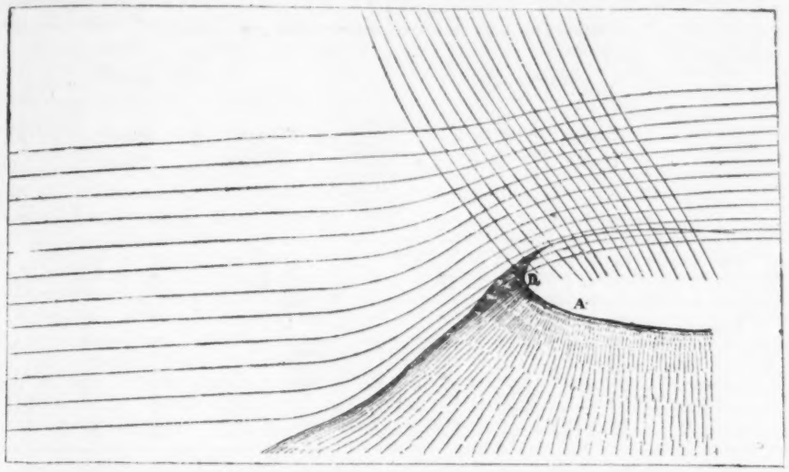

Plate II.—The Effect of Wind uqon the Distribution of Rain on Mountain Summits.

TABLE II.—*Showing the rainfall in windward and leeward gauges.*

Wind.	Windward gauges.	Central gauges.	Leeward gauges.
N.....	C 0·79	B 1·20 D 0·65	A 1·23
NW....	C 26·31 D 24·93		A 29·15 B 28·23
W.....	D 3·70	A 4·92 C 4·02	B 5·13
SW....	A 3·29 D 3·71		B 4·20 C 3·85
S.....	A 4·33	B 8·28 D 6·40	C 6·91
SE....	A 1·24 B 2·69		C 1·87 D 1·65
E.....	B 0·15	A 0·18 C 0·18	D 0·16
NE....	B 1·31 C 1·47		A 1·48 D 1·43

gauges the most of all. This result is in accordance with the law of variation of rainfall on the roofs of buildings stated, as we have seen, by Bache, in 1837. Unless the agreement is accidental, we may conclude, therefore, that the wind acts in the same way in affecting the distribution of rain on the summit of Mount Washington as when obstructed by buildings and towers.

The action of wind currents in producing this increase of rain to the leeward may be illustrated by the accompanying figure (see Plate II.), based on the theory of Jevons, already stated.

Let *A*, *B*, *C*, *D*, be the location of four gauges on the summit of a mountain, *C* being the northern, and *A* the southern gauge, and suppose the horizontal lines to represent westerly wind currents. On reaching the mountain the lines are crowded together and forced upward over the summit and laterally around the mountain sides: the figure representing only those forced upward. The velocity of the wind thus obstructed in its course is largely increased. The course of equidistant raindrops falling under an increasing velocity of the wind will be represented by the intersecting lines. On the windward side of the summit, near the surface of which the wind has attained its highest velocity, the rain is carried over and past the gauges there located and precipitated to the leeward, where the wind has regained a portion of its original velocity. Thus the gauge *D*, situated to the windward during west winds should receive the least rain, *A* and *C* a larger amount, and *B* the most of all. The relative locations of the extra gauges on Mount Washington correspond with the positions above given and the gauges should therefore present these differences. Turning now to the preceding table, we find for west winds $D = 3.70$, $A = 4.92$, $C = 4.02$, $B = 5.13$. A result agreeing exactly with the requirements of the hypothesis. Table II. contains, however, a few apparently discordant results that must receive a separate examination. A portion will thus be found to be exceptions that prove the rule, or, rather, that show how it is modified by other considerations.

1st. The rainfall in gauge *D* during north winds and in gauge *B* during south winds, the former giving the smallest record and the latter the largest record, are two such exceptions.

If now we turn to Plate I. which shows the exact location of the gauges, *B* will be seen to be one hundred and fifty feet nearer the central north and south line of the summit than *D*. Of wind currents, those that strike the mountain near the center will be deflected upward, while those striking the mountain nearer to either side will be deflected laterally and pass *around* rather than *over* the summit. An increased precipitation should accordingly be expected over the locus of the augmented wind current. Thus, with northerly and southerly rain-bearing winds *B* should receive more in than *D*, and we find this to be the case. *A* and *C*, being in a direct north and south line, conform as they should to the law of increase to the leeward.

2. With an east wind, for which we have only one rain storm, the several gauges record almost the same amounts with but a few hundredths variation. This equable result is explained by the anemometer record, which registers, during this storm, a velocity of but about ten miles an hour, being only one-third of the average velocity for the month. As variations are due to the wind, it is evident that the smaller its velocity the smaller will be the variations between the readings of the gauges.

3d. A single prominent exception to the principles above stated is found in the excessive record of gauge *B* as compared with *C* during southeast winds. For the location of our gauges we have found with other winds that the rainfall increases to the leeward, yet at some point a maximum must be reached, beyond which a decrease takes place; so for southeast winds it may be that the gauge *C* is beyond the point of maximum precipitation. The rainfall with easterly winds is, however, so small that the difference due to the locations of the gauges for these winds cannot sensibly affect the monthly or annual directions:

The average of the four gauges gives the following percentages for the amount of rain falling during winds from different directions:

NE.	E.	SE.	S.	SW.	W.	NW.	N.
.03	.00	.04	.14	.08	.10	.59	.02

By far the largest part of the whole rainfall is thus shown to occur with northwest winds. We should, therefore, expect that gauge *B*, which is to leeward with respect to northwest winds, and nearer to the center of the summit than *A*, would present the largest annual record of all the four gauges, if the principles above stated be correct. The totals of Table I. show this to be the case.

In the preceding discussion the records of the station gauge, having a receiving surface eight inches in diameter, have not been included, owing to the fact that its measurements were found to be uniformly much greater than those of the three inch gauges. The total amount of the station gauge, covering the same periods as the totals of the four extra gauges given in Table I., was 58.70. This excess, occurring with winds from all directions, is to be explained by a difference in the collection arising from the difference in the sizes and patterns of the two styles of gauges. From the above observations, however, the portion of the variation due to the peculiarities in the gauges can not well be separated from the variation dependent on a difference of location.

During July, 1883, a series of observations was made with the station gauge and a three inch gauge in which the latter was placed a short distance from the station gauge and located so as to be under, as nearly as possible, the same influences. In this series of observations the differences due to location and environment are as far as possible eliminated, and a direct comparison of the two gauges in collecting rain can be secured. Table III. gives these observations arranged according to the velocity of the wind:

TABLE III.—*Giving results of comparative readings of eight inch and three inch gauges.*

Wind velocity (miles per hour)	15		40		60		75	
	3 in.	8 in.	3 in.	8 in	3 in.	8 in.	3 in.	8 in.
Amount of rain	1.75	1.84	2.77	3.37	1.60	2.44	1.87	3.49
Percentages	100	105	100	122	100	152	100	186

The following empirical formula, obtained from the above results, represents the observations with a sufficiently close approximation, $\frac{G_8}{G_3} = 1 + .015x^2$ in which G_8 and G_3 are the amounts collected by the eight inch and three inch gauges, respectively, and x the velocity of the wind in units of ten miles per hour.

The discrepancy between the measurments of the two gauges varies, therefore, directly as the *square of the velocity of the wind*, and is due to insufficient collection by the smaller gauge.

By means of this formula the totals of the small gauges given in Table I. can now be rendered comparable with the total of the station gauge.

The average velocity of the wind during rain was, as nearly as can be determined, about forty-five miles per hour. For this wind velocity the formula gives thirty per cent. as the factor by which the totals of the three inch gauges must be increased in order to correspond to the station record. The totals of the gauges will then be $A = 59.37$, $B = 66.55$, $C = 59.02$, $D = 55.42$, station $= 58.70$. In this system of values the station record agrees with the law of distribution of rainfall already obtained.

The deductions from the two series of observations are thus, as far as they go, confirmatory of each other.

The large difference above found, in the collection of rain by the two sizes of gauges does not agree with the observations of English and Continental meteorologists. After collecting all available data relative to the question, Prof. H. Mohn, Director of the Meteorological Institute of Norway, made a special report to the International Meteorological Congress held at Rome in 1879, in which he says: "From the foregoing facts it is evident that the size of the receiving surface exerts no influence as long as the diameter does not sink below three English inches." Whereupon the Congress reversed the decision, made at Vienna in 1873, by passing the following resolution: "The Congress thinks that for stations of the second and third order, a diameter of eight or even four inches is sufficient for the rain gauge."

This accordance, observed by Symons and Mohn, between the records of three inch and larger gauges is probably due to the fact that the observations were made only during relatively small wind velocities, in general not exceeding twenty miles per hour, and the average of which was probably less. If this was the case, Prof. Mohn's decision in no way affects our conclusion that, for stations with very high winds, the three inch gauge gives insufficient records and that the deficiency varies with the square of the wind velocity.

The results obtained from the above observations confirm the statement made at the outset of this paper, and in illustration of which this investigation has been undertaken, namely, that special comparative observations are necessary if we are to have any accurate knowledge of the significance to be attached to rain gauge records, and of their value as meteorological and climatological data.

Fish and Sewage.

In a recent report from Mr. Noake, who is one of the Severn commissioners, there is found the following statement regarding the viability of fish in contaminated water, which is somewhat different from views generally obtaining on this subject. Mr. Noake says:

"It is a remarkable fact that at the meeting of the Severn commissioners recently at Worcester, the report stated that the salmon disease had entirely disappeared during the late summer. The past season has been the longest, warmest and dryest known in the country for many years, and as the Severn was correspondingly low, it must have been more than usually polluted (in proportion to the small quantity of water), yet the fish disease disappeared. I am also informed by fishermen that some sorts of fish are so well known to congregate near the mouth of sewers that anglers and others make it a rule to seek and find them there. This seems to imply that diluted sewage is attractive to these fish, either as an alterative in their diet or medicinally, or otherwise grateful to the piscine stomach. These facts, no doubt, confuse, if they do not reverse, our ideas as to the destruction of fish by the pollution of rivers. Where chemicals or other pungent refuse from manufactories are introduced into our streams there can be no question as to their baneful effects on fish life, but that the sewage of towns is not objectionable to these creatures is a fact which ought to be taken into account in any further pollution of rivers act. The argument hitherto urged, and unanimously accepted, that the discharging of sewage into our streams tended to the destruction of the fisheries would seem to be no longer tenable."

The Creeping of Rails on the St. Louis Bridge.*

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There is an interesting phenomenon connected with the operating of the St. Louis Bridge, a satisfactory explanation of which has never come to the writer's notice, and a safe means of preventing which has not yet been found. The object of this paper is to describe the action, to offer an explanation of the cause, and to suggest a remedy.

The phenomenon consists in a movement of the rails, forming the track, of about *a foot a day*. This movement is always in the direction of the traffic. It being a double track bridge, the traffic over the north track is always westbound, while that over the south track is always east-bound.†

The creeping is confined to the bridge proper and to the eastern approach, which is a series of short girders on iron columns. The approach is on a grade of 80 feet per mile and is 2,500 feet long. The tracks are crowning over the bridge, which is 1,600 feet long, the grade at the centre being 5 feet higher than at the abutments.

The amount of the creeping is greatest on the approach, being for the year, Sept. 1, 1883, to Sept. 1, 1884, in the ratio of 162 to 100. The ratio of the corresponding distances is approximately 156 to 100.

Various methods have been employed to hold the rails in place, but never with success. Steel spikes, bolts, straps and splice bars have been sheared off and torn asunder; frogs, crossings and connecting tracks in East St. Louis pulled out of line, and the rails themselves so buckled and twisted that when one was removed it could not have been replaced again by eight inches. Finally it was no longer considered profitable to try to hold them, for if they should succeed in holding them to the structure then these great strains would come upon it, and this would be more objectionable than to leave them free to move and correct it constantly by cutting out and replacing.

There is no creeping in the tunnel, though the traffic remains in a single direction, as the double track extends through to the Union depot.

Provision is now made for this movement at three points on each track, viz.: at the entrance upon the east approach, at the east abutment, and at the west abutment. On the north track, since the rails go west, openings are constantly enlarging at the approach and closing at the west abutment. On the south track the rails go east, so the openings are enlarging at the west abutment and closing at the approach. Where the openings are enlarging, short pieces of rail are taken out and longer ones put in their place, and where they are closing up, longer ones are removed and shorter ones inserted. This has to be done many times a day at each point where the rails are cut. On account of the switches located at the east abutment, it is necessary to have cut sections each side of these, making four places on each rail where this movement has been provided for. Every second day the foreman in charge of the day squad measures the movement that has occurred, on both approach and bridge, and keeps a careful record of the same. The monthly movements are copied into the reports and are on file in the offices of Mr. Wuerpel, the Superintendent of Structure, and of Col. C. Shaler Smith, the engineer of the bridge company. In these monthly reports, the movement of a given rail on the approach is added to its movement on the bridge, thus showing the work done in splicing on that rail; but these amounts must be separated again for any discussion of these movements. In Table I. the amounts were copied directly from the foremen's note books, and the true movements kept distinct.

Table II. is compiled from the records on file in the offices of the Manager and Superintendent of the bridge. The tonnage has been computed by allowing 80,000 lbs. as the weight of an engine, 55,000 lbs. as the weight of a loaded car, 18,000 lbs. as the weight of an empty freight car (they are largely coal cars), and 40,000 lbs. as the weight of a passenger car with its ordinary load. The engine weight was furnished by the Master Mechanic and the other values are the estimates of the officials of the company. From the total movement for the year, Table I., we have the following relations:

The ratios of the movement on the approach to that of the same rail on the bridge are respectively: 1.49, 1.54, 1.72 and 1.73, or an average of 1.62. The ratio of the corresponding lengths of tracks is 1.56. The mean westward movement for the year on the approach (up a grade of 80 ft. per mile) was 401 feet.

The corresponding eastern movement (down the same grade) was 414 feet.

The mean westward movement on the bridge was 264 feet.

The mean eastern movement on the bridge was 240 feet.

The western movement on the bridge was 110 per. cent. of the eastern movement, while on the approach the westward (up grade) movement, was only 97 per cent. of the eastern movement, or a difference in these west to east ratios of 13 per cent., which is doubtless due to the effect of the heavy grade on the approach, the expansion and contraction from temperature causing mostly a downgrade movement.

From Table II. we see that the ratio of the westward to eastward tonnage for the year was 1.099, while from Table I. we see that the ratio of the mean westward rail movement to mean eastward movement was also 1.099. This extreme coincidence is of course accidental, but if these percentages be compared month by month, it will be seen there is a common law pervading both. Here on the bridge this ratio is not affected by the grade, for it is symmetrical with reference to the two movements. This identity in the ratio of the movements with the ratio of the tonnage west and east would of itself lead us to conclude that the movement is proportional to the tonnage. On the other hand, we see that the ratio of movement on approach to that on the bridge is 1.62, while the corresponding ratio of the distances is about 1.56. From this we might infer that the movement is proportional to the length of structure. The increased movement on the approach *may* arise, however, from more favorable conditions there for movement, and the close agreement in the ratio of the movements on approach and bridge, with that of their distances be purely accidental. Conclusive evidence on this point will appear below.

The St. Louis bridge is not alone in this matter of rail movement. The Pennsylvania Company had trouble on their Harrisburg

TABLE I.

MOVEMENT OF RAILS ON THE ST. LOUIS BRIDGE AND APPROACH.

Month.	Approach (2,500 ft.). N. track. (West.) N. rail.	Approach (2,500 ft.). N. track. (West.) S. rail.	Approach (2,500 ft.). S. track. (East.) N. rail.	Approach (2,500 ft.). S. track. (East.) S. rail.	Ratio: Mean north track / Mean south track	Bridge, (1,600 ft.). N. track. (West.) N. rail.	Bridge, (1,600 ft.). N. track. (West.) S. rail.	Bridge, (1,600 ft.). S. track, (East.) N. rail	Bridge, (1,600 ft.). S. track, (East.) S. rail.	Ratio: Mean north track / Mean south track
1883	In.	In.	In.	In.		In.	In.	In.	In.	
September	382	388	382	380	.99	248	250	227	227	1.10
October	408	410	434	446	.92	234	230	229	228	1.02
November	390	390	400	400	.97	270	270	224	224	1.20
December	404	408	430	434	.94	272	278	240	244	1.14
1884										
January	389	400	410	422	.96	284	282	247	247	1.15
February	390	390	403	404	.97	266	271	241	241	1.11
March	390	388	400	400	.97	240	231	234	234	1.01
April	394	393	407	411	.96	239	238	241	242	.99
May	408	410	413	409	1.00	297	283	263	248	1.14
June	401	399	420	421	.95	269	268	255	257	1.05
July	406	404	416	406	.99	266	234	222	222	1.12
August	435	437	447	446	.98	286	284	263	259	1.09
Year	In. 4806 Ft. 400	In. 4867 Ft. 401	In. 4962 Ft. 414	In. 4976 Ft. 415	.97	In. 3211 Ft. 268	In. 3119 Ft. 260	In. 2886 Ft. 240	In. 2873 Ft. 239	1.099

TABLE II.

TRAFFIC OVER THE ST. LOUIS BRIDGE FOR ONE YEAR.

Month.	No. engines east	No. engines west.	No. freight cars east—loaded.	No. freight cars east—unloaded.	No. passenger cars east.	No. freight cars west—loaded.	No. freight cars west—unloaded.	No. passenger cars west.	Total tonnage east.	Total tonnage west.	Ratio— (West tonnage. / East tonnage.
1883											
September	2,071	2,071	5,855	6,834	4,893	3,104	3,939	4,952	403,200	467,700	†1.16
October	1,950	1,950	4,058	3,732	5,678	6,615	1,522	5,690	336,800	359,900	1.07
November	2,146	2,146	4,501	6,516	4,676	9,681	1,789	4,744	362,300	463,000	1.28
December	2,104	2,104	5,920	5,849	4,770	7,878	3,363	4,828	396,600	427,600	1.08
1884											
January	2,245	2,245	6,697	8,927	4,747	10,994	2,309	4,798	449,200	508,900	1.13
February	1,976	1,976	5,729	7,449	4,258	8,158	4,313	4,275	388,900	427,700	1.10
March	2,101	2,104	7,466	6,700	4,792	8,316	4,455	4,839	445,500	449,600	1.01
April	1,990	1,990	6,297	6,090	4,741	6,533	4,485	4,754	402,400	394,700	.98
May	2,140	2,146	6,253	8,375	4,958	6,957	4,482	4,965	405,100	444,000	1.09
June	2,109	2,109	6,322	5,787	4,996	7,498	4,328	5,017	410,200	429,800	1.04
July	2,148	2,148	5,958	5,971	5,118	7,527	4,707	5,125	401,800	437,700	1.09
August	2,138	2,138	5,797	6,673	5,006	9,213	3,653	5,024	405,100	472,200	1.16
Total for year	25,118	25,118	70,853	75,903	58,633	97,474	43,345	59,011	4,806,500	5,282,800	1.099

* From *Journal of the Association of Engineering Societies*, Nov. 1884.

†This is sometimes reversed to overcome a tendency the arches have to take on a distorted shape, in which the crown of the curve is moved away from the centre in the direction of the traffic.

bridge over the Susquehanna, while it was still a single track. The traffic was heavier, however, going east, and the rails crept in this direction. The exact amount of the creeping was never known, but the fact of creeping was shown by the displacement of the curves at each end of the bridge, as much as four feet of track being removed from one end of the bridge and replaced at the other at one time. The movement was stopped by the use of a splice such as is shown in Fig. 1. *

The splice is an angle bar which projects over the flange of the rail at bottom and rests on the tie. Four spikes are notched into the bottom flanges of a set of splice bars, and there are sufficient to keep the rail in place even now, with the bridge changed to double track and the traffic all in one direction on each track. The cause of the efficiency of this device will be referred to in discussing remedies.

Rails are always observed to creep on heavy grades, but this is probably mostly due to the expansion and contraction from temperature, and is no function of the direction or amount of the traffic. In both expansion and contraction there must be a movement on the ties, and this movement will always be in the direction of the least resistance. On heavy grades of considerable length, the least resistance will be toward the foot of the grade, and there will be a general movement in this direction. On any line of road, where the traffic is all in one direction, there is always observed a *tendency* toward creeping, all along the line, in the direction of the traffic. The amount of such creeping is usually small and can generally be resisted.

An analagous action is the creeping of bridges on their supports. A study of this very plain case is likely to throw considerable light on the creeping of rails.

If a bridge have its two ends similarly mounted, whether both on rollers, or both on slides, when a train comes upon it from the right, this end is at once pinned fast by the weight of the train, and as the train moves over the bridge it causes a certain amount of deflection in the truss. This deflection lengthens the bottom chord and shortens the top one, so that if the truss is supported at the bottom chord, the left end moves to the left, but if it is supported at its top chord, as deck bridges sometimes are, the left end will move to the right. I have observed this movement when it amounted to as much as three-fourths of an inch. As the train goes off the truss recovers its normal position, the lower chord shortens up and the upper one lengthens out, but now the left end is pinned fast by the departing train while the right end is free to move. The recover will take place at this end, therefore, so that if supported at the bottom chord the truss is pulled forward, and if supported at the top chord it will be moved backward by an amount equal to the distortion of the corresponding chord. If it is a single track bridge, with traffic equal in both directions, its movements will compensate, and so will not crawl off the piers. If the traffic is unequal, the truss will move in the direction of the heavier traffic when supported at bottom, and against the heavy traffic when supported at top. If one end is on rollers and the other anchored fast to the pier, then, of course, the movement all occurs at the roller end, regardless of the direction of the train. I have understood that the Louisville bridge moved north from this cause by some six inches, when it was found necessary to anchor one end fast to the pier. All bridges will act in this manner when both ends are treated *alike*, whatever that may be.

Causes Assigned for the Creeping of Rails on the St. Louis Bridge.

Many causes have been assigned for the creeping of rails on the St. Louis bridge. I will enumerate some of these, with what I conceive to be the objections in each case. Some of these assigned causes are the result of no study of the facts in the case, and like most imaginary causes of hypothecated phenomena, they are either not pertinent or not sufficient to the case in hand.

1. That it is due to the grades. But the creeping is nearly as much up grade as it is down.

2. That it is due to the stopping of trains on a down grade. This at first appears plausible, for the trains generally are stopped on a down grade going west at the west abutments, which would apparently pull the rail in the same direction, and this is what is observed to occur. But these rails are continuous only over the bridge, being cut at the east abutment, and trains do not stop going west on reaching the east abutment; therefore this cause does not explain the westward creeping, on a stiff up grade, of the north track on the approach. The creeping on the approach being greater than that on the bridge, and wholly unaccounted for on this hypothesis, it must be rejected.

3. That it is caused by the tapping or pounding of the wheels against the rear ends of the rails, thus driving them forward. If this be true, it should be the same in the tunnel, or on any ground track, as on the bridge. Again, it would appear comparatively easy to resist this action by proper holdings, whereas the tendency found to exist is almost irresistible. Besides, with the modern splice, the rails are held so nearly at the same elevation, and so close together, that it is difficult to see how very much of a blow could be given by the wheel.

4. That it is due to the deflection of the bridge itself by the train load. This is also a plausible theory, inasmuch as the track is crowning over the bridge, so that when the middle arch is compressed and lowered by the train load, the rail must be shoved ahead a little, since the rear end must be held fast by the weight of the train. I am inclined to believe this cause is good so far as it goes, but that it does not go near far enough. For, the track is crowning, in a single curve, over the three arches, rising five feet in a distance of 1,600 feet. If now the middle arch is depressed so as to bring the track horizontal over this arch, it would cause a flattening of but one foot in the track, and this flattened track would be shorter than the normal curve by only *four one-thousandths of a foot*. The grade being straight over the end arches, any deflection of these would cause the track to sag, and so pull back on the rails from in front. The actual movement for one train is often as much as half an inch, or 40 one-thousandths of a foot. This cause does, therefore, not go far enough. Besides, it fails to account for any movement on the approach. Again, if this were the cause, the foward movement noted for any train should be observed to take place *ahead of the train*, whereas, when we closely observe the action, it is found to occur *only during the passage of the train*.

5. That it is due on the bridge to the *distortion* of the arch. When the train load comes upon the arch from one side, this haunch is flattened somewhat and the forward haunch is lifted, resulting in a forward movement of the crown of the arch. When the train goes off the flattening is on the forward side, resulting in a backward motion of the crown, but now the rail is pinned fast at the forward end of the arch, so that the arch would *slip backward under the rail*, and then, as it rights itself again, when the train has passed, it pulls the rail forward with it. If this were the explanation, which would not apply to the approach at all, then, the following actions should be observed at the pier, or abutment, at the forward end of the arch in question: First, a forward movement of the rail as the train comes upon the rear half of the arch; second, a backward movement, as the train comes upon the second half of the arch, due to the arch settling back to its normal position; third, no movement under the train itself at the forward pier. After many days observations, I have been unable to detect any such action. On the contrary, the movement all seems to occur during the passage of the train.

6. That it is due to the pæning of the rail. As the wheels roll along over the rail, each one flattens out, or pæns the rail somewhat, immediately under the wheel. Most of this effect is a temporary distortion, the rail recovering its normal shape after the load has passed off; but a small part of it is permanent, so that an old rail is somewhat longer than when it was first laid. This permanent effect is proportional to the tonnage and to the length of the track, but for the 1600 feet over the St. Louis bridge the permanent increase of length of one track would not certainly be more than a few inches for one year, whereas the movement is 260 feet. The creeping from the temporary distortion, or pæning, would be much greater. This is best conceived by thinking of a heavy roller moving over a strip of india rubber. The spreading of the rubber under the wheel is lengthwise as well as sidewise, and so far as it is lengthwise, by so much will the rubber strip move forward. This effect is also proportional to both tonnage and distance. It would also be greater for a rail supported in a continuous stringer than for a rail laid on ties. It would be impossible to accurately compute this effect, but I think it must be very small.

The last three causes, 4, 5 and 6, are those assigned by Col. Shaler Smith, the engineer in charge of the bridge. They are all good so far as they go, but their combined effect does not seem sufficient to account for the great movements we find on the bridge, and only the last one can be applied to the approach.

A strong objection to all the causes of movement assigned above, is that they involve the actual slipping of the rails upon the ties, this slipping occurring with the first three assigned causes while the train load is on, and in the other two causes occurring ahead of the train. It is quite impossible that the rail should slip on the ties, when the train load is on. For instance, in a train of twenty loaded cars, weighing 55,000 lbs. each, with a sixty-ton engine, we have 610 tons of load on the rails. If the coefficient of friction between iron and wood be taken as 50 per cent., we would have a resistance to slipping of 305 tons, or 305,000 lbs. for each rail. If we allow a strength of 50,000 lbs. per square inch for iron, rails of six sq. in. in cross-section would be torn asunder before these rails could be made to slip on the ties. (This cross-section is that of a 60 lb. rail.) This is also the measure of the force necessary to keep the rail from moving, which seeming paradox will be understood when the chief cause of movement is explained.

The True Cause of Creeping.

The true cause, as the writer conceives it, of the creeping of rails due to traffic upon them, has not come to his notice, though he has no doubt but it has often been similarly explained. The explanation is very satisfactory when once examined, and carries conviction with it, but it seems to have been generally overlooked.

One will be the more ready to accept the explanation about to be offered, if the phenomenon itself be first fully described. The method of observation was as follows: Mark with a lead-pencil a continuous line from the lower flange of the rail, over the head of a spike, at right angles to the rail, When a train passes, observe two things, the wave motion of the rail and the increments of forward movement every time a wave passes and the rail is again pressed down upon the ties. It was found that, between the tracks of each car, the rail lifts itself free

* For this Fig. 1 see Fig. 39 in the article on "Track" in this issue.

from the ties, raising a quarter of an inch or so, and when the rear truck comes along and presses the rail down at the marked sections, it has moved forward a little. There is a small wave in front of the engine, and a corresponding movement, but apparently no greater then under any single car. The wave under the car is higher, not from the heavier loads on trucks, but from there being a load both before and behind, each of which tends to lift the rail between. This upward curving of the rail is due to the elasticity of the supports. On the bridge, the rail rests on blocks of gum wood, 5½ inches thick, which are held between 12 inch channel bars, as is shown in Fig. 2.

These pillow blocks are 17 inches long, with alternating spaces of 19 inches. The elastic action of these blocks gives the rail a wave motion *independent of the deflection of the channels.*

On the approach, the rail rests on a two-inch oak plank, laid longitudinally, this plank resting on cross-ties, 8 inches wide, with spaces of 10 inches.

On both bridge and approach, the rails are left free to move, being held together by the

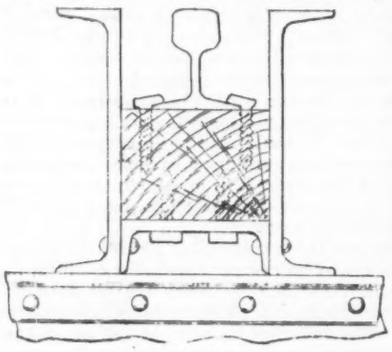

FIG. 2.

Sampson splice bar, being a plain bar without flanges.

The pertinent facts then are, that there is a wave motion of the rail, independent of its supports, such a wave occurring under each car and moving with it, giving a slight forward motion to the rail every time a given section is brought down upon the support. Evidently the total movement for one train varies with the weight and number of cars in the train, or with the tonnage of the train.

When the *manner* of the action is explained, the *cause* follows very naturally. The rail is held fast on the ties *on its extended side.* This causes the rail to measure its length across the bridge on its extended flange. If but one wave of this sort passes over the bridge, the effect is cumulative, and the movement increases with the length of the bridge. If a series of waves pass, the effect of all waves after the first is a constant quantity. A detailed explanation may be given by the aid of Fig. 3.

For simplicity, let the depression be caused by a single wheel at P, moving toward p. Let pp' be a vertical section parallel to PP'. On account of the deflection of the rail, the normal section at n' is oo', the lower fibres being extended from $P'p'$ for a horizontal position to $P'o'$ for the deflected condition. In other words, the point o' has moved forward from p' as a result of the deflection, the point P' being fixed by being held fast to the support by the load. As the load moves toward p the depressed portion of the wave moves with it, and when the load reaches p the normal section oo' has come to coincide with the vertical section pp' *by revolving about o' as the fixed point.*

The secret of the whole matter is, that the rail rolls itself across the bridge on its outer, or extended side, and by as much as this is longer than the neutral axis, by so much it will creep for a *single* wave passing. This amount is directly proportional to the length of the structure, and to the amount of the deflection. If another wave follows this, however, its additional effect will be constant, and

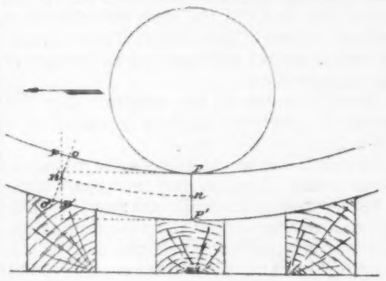

FIG. 3.

will not increase with the length of the structure; in other words, this and all succeeding wave effects of the series will be directly proportional to the deflection alone. The total train effect will therefore be proportional to the weight and number of cars passing—in other words, to the tonnage of the train. This has been seen to be true on the bridge. On the approach the effect of the grade comes in to modify this ratio.

From the above reasoning it is evident that if the rail were supported at a point above the neutral axis, as under the head, for instance, there would be a tendency to creep backwards, or against the direction of the traffic, from the compression of this upper side. There would still be a forward tendency, however, due to the wave motion of the rail, inasmuch as the neutral line of the rail, when thrown into waves, is longer than the corresponding linear distance. If the rail be supported from the upper surface, as has been done in the model to be exhibited, then the backward motion due to the compression of the upper flange would more than counterbalance the forward motion due to the waves in the neutral axis, and the rail would actually move backward.

If these opposite actions can be shown to occur, as here described, then there is evidently a point of suspension somewhere between the neutral axis and the upper surface, from which, if the rail be suspended, there will be no tendency to move either forward or backward.

Some English rails are supported from the lower side of the upper flange, or head, and it is said their tendency to move forward is much less than that of the American rail.

It may be objected to this theory that this action obtains on the ground as well as on bridges and trestles, True, it does; and there is also a strong tendency to creep on the ground, but not so strong but it can be resisted. This is on account of the yielding nature of the soil and ballast. If the ties were fastened as rigidly to the ground as they are to bridges, and if the wave motion were as great, the tendency to move in the direction of a continuous traffic would be quite as great.

It is evident that it is not the absolute deflection of the rail that is significant, but the wave motion of the rail independent of the motion of the supporting track system. If the rails were fastened down snug upon the stringers, so that they deflected with them strictly, the rail would have no tendency to crawl upon the stringer. In the case of the Pennsylvania bridge, at Harrisburg, the splice bars fit snug under the head and rest on the ties, so supporting the rails, at the ends at at least, above the neutral axis. Each set of splice bars is also held in place by four spikes, making four spikes to each rail that would have to be sheared off in order to move the rail. The rail would evidently slip on the ties, with its load on, before it would do this. When the attempts were made to hold the rails on the St. Louis bridge, the holdings were concentrated at isolated points on the line, so that the crowding action accumulated for a considerable distance, and the holdings gave way before this longer reach of rail would slip on the supports with the loads on. If each rail were held independently, as is done on the Harrisburg bridge, the creeping could probably be stopped on both the bridge and approach, but it is feared this would bring too great a strain on the truss members. The solution offered above, of supporting the rail under its head, would be a more satisfactory method of treatment, inasmuch as it would utterly destroy the *tendency* to move, and hence there would need be no strains introduced by spiking it fast. The time of eight men is now mostly occupied (five by day and three at night) in correcting the movement, as it occurs in the St. Louis bridge, but it is claimed this is no expense to the company, as they would have to keep so many trackmen in employment anyway, and they might as well be kept busy. It would seem, however, that a considerable portion of this expense could be avoided by wholly stopping the rail movement. The only way of doing this without straining the structure is by destroying its *tendency* to move, and this can only be done by supporting the rail above the neutral axis, or in such a manner as to destroy its independent wave motion.

From the above explanations, one can understand the seeming paradox, that the rails creep a foot a day, and yet do not slip on the ties. And further, that to hold them in position when supported on the bottom, they must be made to slip on the ties when the load is on, and the force necessary to cause them to do this is the measure of the force required to hold them in place.

In the fore part of this paper the striking coincidence of relative movements and relative lengths track on bridge and approach was noted, but not explained. Two possible causes were suggested, and, in fact, both are found to act. Of the many waves formed in in the rail by the passage of a train, only the small wave in front of the engine is cumulative in its effect, or has its effect of translation directly proportional to the distance traversed. The others all have a constant effect. This would, therefore, have little influence, and if this cause acted alone, the movement ought to be about the same on bridge and approach, regardless of their relative lengths. The other cause, viz., more favorable conditions for movement on the approach is more effective, inasmuch as here the rail rests directly on a continuous stringer laid on top of the ties while on the bridge it rests on isolated blocks, with interviewing spaces of 19 inches each.

In the case of the stringer there is no giving in the suppports, in a longitudinal direction, for it is pinned fast at intervals, and is a continuous member. In the case of the blocks, they doubtless do yield slightly in a longitudinal direction, even under the load, and then recover again, as the rail lifts from between the depressed portions of the track. The rail does not, therefore, move so much forward on account of a sort of backward rocking of the blocks. This same condition of freedom to rock back and forth a few hundredths of an inch obtains on all land-track systems, and so the movement of the rail is easily resisted. In the tunnel the rail is laid on a stringer also but it is so large as not to deflect appreciably, and as the rail is spiked close to this stringer, it can have no independent wave motion, and so has no tendency to creep.

[*Note.*—On the occasion of the reading of this paper before the St Louis Engrs. Club, a working model was exhibited which furnished an ocular demonstration of the theory herein advanced for the cause of the creeping of rails. A circular track composed of a wooden rail 1 inch deep by ¼ inch wide, made of hickory, rested on 16 radial ties which were supported at the outer ends by springs of coiled wire. These outer ends were held rigidly against any lateral motion, but were free to move vertically. The rail was not fastened to these ties but simply held in guides that kept it in place, concentrically, it being free to take on an independent wave motion, and to move longitudinally around the cir

cle. On this track a car was made to run. The car consisted of a plank forming a diameter to the circle, with a wheel at each end. A vertical axis at the centre held this plank in position while it was free to revolve horizontally. This plank was then loaded with some four hundred pounds, and made to move around on the track. The track was thrown into two great waves, being depressed about an inch below its normal position under the wheels, and raised about the same amount above the ties on the other quadrants. The rail was found to move rapidly in the direction of the motion of the car, so that when the car had completed three revolutions the track had moved one inch. This was the case in whichever direction the car was moved.

Thus far the experiment had only proved what has already been observed on the bridge. In order to show that our explanation was the correct one, it became necessary *to suspend the rail from the upper side*, to see if the rail would then move *against* the motin of the car. This was done by screwing iron plates to the top of the rail, allowing them to project over the sides and then supporting these on blocks. The rail was now hung from its upper surface, and, according to the theory herein advanced, it ought to move backwards. *This it was observed to do, whatever the motion of the car.* The amount of the backward motion when supported on the bottom, as indeed, it was not expected to be, on account of there being a forward tendency in both cases, of an amount equal to the excess in length of the contorted neutral axis over its projection on the horizontal plane. The compression of the upper fibres being more than the excess in length of the contorted neutral axis over its projection, the rail moves backward by this much. If the fibre could be found, somewhere above the neutral axis, whose compression would just equal the above neutral axis excess, there the rail would have no tendency to move in either direction.

OUR MATHEMATICAL COLUMN.

PLATO maintained that those who did not understand the one hundredth and seventeenth proposition of the thirteenth book of Euclid's Elements ought not to be ranked among reasonable creatures. The thirteenth book of Euclid is unfortunately lost, so that we are unable to appreciate the exact force of Plato's criterion, yet it is generally thought to have been a severe and unjust one. Many a contractor who does not understand the first proposition of the first book can reason well enough to make good profits out of his jobs. Nevertheless the contractor would reason better if he knew a little geometry.

THE ALMANAC for January, 1885, contains nothing of striking interest. There are two full moons, one on the 1st, and the other on the 30th. On the last day of the month the sun rises about twelve minutes earlier and sets about thirty minutes later than on the first day, and as the days begin to lengthen the cold begins to strengthen. Mercury and Venus may be seen in the east before sunrise and the former attains its greatest brightness on the 26th. Mars, Jupiter, and Saturn may be seen in the west after sunset. There are no eclipses. The almanac says nothing about earthquakes, but signs indicate that they are liable to come. The dominical letter for the year is D, the epact is 14, and the golden number is 5. About the end of the month a decided improvement in business is expected.

HENRY A. JONES explains a new method of abridged division in his little work, recently published, entitled "An aid to numerical calculation." It consists in dividing the given number by a convenient divisor slightly larger than the real divisor, then multiplying the quotient by the difference between the two divisors and adding the product to the first remainder. For example, let it be required to divide 3845 by 78¾. Select 80 as the convenient divisor, then 80 into 3845 gives 48 quotient and 5 remainder, and to this remainder is to be added 48 times 1¼, or 72. The required answer is therefore 48 quotient and 77 remainder. In cases where the remainder is larger than the given divisor, such remainder must be treated as a new dividend, and the process be continued. For instance to divide 1769½ by 9¾; selecting 10 as the convenient divisor, we have 176 quotient and 9½ remainder, to this remainder add 176 times ¼ or 44, giving 53½; consider now 53½ as a new dividend and divide it by 10, thus finding 5 quotient and 3½ remainder, to 3½ add 5 times ¼ or 1¼, which gives 4¾ as the final remainder; the sum of the two quotients 176 and 5 is 181, and hence the final result is 181 quotient and 4¾ remainder. The process is curious, and for purposes of mental calculation will often prove useful in the division of fractional numbers. Nearly all practical computations, however, require the quotient to be carried out to several places of decimals and do not allow that a remainder should be left over.

THE CENSUS reports show that a large number of the people of the United States either do not know their own ages or give false answers in stating the same. For instance the census of 1880 shows that there are 460,000 people of age 39, 920,000 of age 40, and 320,000 of age 41. Here evidently a large number have stated their age as forty who are either older or younger. If the law of mortality were known it would be possible to write an equation giving the number of people y who are aged x years in terms of the total population P. The law, however, can only be obtained from statistics, and as these are defective the investigation is a complex one. Dr. H. E. Licks, who has spent some time in discussing this important subject, has deduced an empirical formula, and has sent us a table comparing the computed number of people at each age in 1880 with the number as stated by the census. The following extract from the table shows the irregularity of the actual returns as well as some indication of the number who give erroneous statements. The first column gives the age, the second the enumerated number of that age, the third the computed number, and the fourth the difference between calculation and observation. The numbers are given to the nearest ten thousand only. It

Age.	Enumerated.	Computed.	Difference.
30	1,000,000	790,000	+ 300,000
31	490,000	770,000	— 180,000
32	650,000	750,000	— 100,000
33	680,000	730,000	— 150,000
34	550,000	700,000	— 150,000
35	870,000	680,000	+ 190,100
36	580,000	666,000	— 80,000
37	500,000	640,000	— 140,000
38	490,000	620,000	— 130,000
39	460,000	600,000	— 140,000
40	920,000	580,000	+ 340,000

will thus be seen that about 180,000 persons of age 31 failed to give correct answers to the census enumerators. From his entire table Dr. Licks finds that the sum of all the negative differences is 3,720,000, and hence concludes that at least that number of people out of the entire population of 50,160,000 erroneously stated their ages. In other words at least seven or eight per cent of definite statements of age are in error by one or more years.

TO REDUCE stadia or telemeter readings when the line of sight is inclined to the horizontal, tables are generally employed. In the absence of such, reduction tables the reading may be reduced, to the horizontal by multiplying it by the square of the cosine of the inclination. To prove this, suppose the rod to be held perpendicular to the line of sight; then the horizontal distance would evidently be equal to the product of the reading by the cosine of the angle of inclination. But as the rod is always held vertical, the actual reading is greater than that just supposed in the same ratio as the secant of the inclination to unity. Therefore the actual reading is to be multiplied twice by the cosine, or, what, is the same thing, by the square of the cosine, in order to obtain the reduced horizontal distance. The correction to be applied to make the distance count rom the center of the instrument instead of from the point in front of the object glass, is usually small, and should be added separately if at all.

PROBLEMS are very useful in exciting the interest of the young and in educating them to think rapidly and exactly. In this column a few will be occasionally proposed to which the answers with outlines of the solutions will be subsequently given. Simple questions from text-books will not be admitted, and useless perplexing problems, like that which asks the profit made by a contractor who sold a horse for ninety dollars, bought it back for seventy-five and sold it again for eighty, will not be allowed to puzzle our readers. For this month there are proposed the three following:—

1. The perimeter of a triangle is 24 feet, the radius of the inscribed circle 2 feet, and the radius of the circumscribed circle 5 feet. What are the three sides?

2. A clean cast iron pipe 2 inches in diameter and 1,200 feet long delivers water from a reservoir under a head of 230 feet. What is the horse power of the issuing stream?

3. Prove that most economical depth of a bridge truss with parallel chords is that for which the quantity of material in the chords is approximately equal to the quality of material in the webbing.

Correspondents who forward us solutions of these problems are requested to note that it will be best to state them with as little algebra as possible. Probably algebra will be required for working out each of the above problems, but it will not be necessary to write it down in full in order to explain the principles and method of solution. Algebra is merely a tool by which the operations of the mind are rendered quick and effective, and would not be needed at all if our reasoning abilities were more powerful. A very satisfactory statement of the solution of a problem may often be made without the use of any symbols save those of arithmetic.

E. B. WINGATE, late Chief Engineer of the Indianapolis Union Railway, has been appointed Assistant Engineer of the Government of Guatemala, South America, at a salary of $6,000 per year, with expenses from this country to Guatemala paid. MR. WINGATE will leave for his new field about the middle of next month.

PERSONAL.

JOSEPH K. CHOATE was appointed General Superintendent of the Nevada Central R. R., on Dec. 15. Headquarters at Battle Mountain, Nevada. He succeeds F. W. Dunn, resigned.

C. S. FRANCKLYN, of New York, was elected president of the Hartford & Harlem R. R., on Dec. 27. Only about half a dozen people attended the annual meeting held in New Haven on the above date.

COLIN R. WISE, Chief Engineer and Supt. of Construction of the Brunswick & Western R. R., is also appointed Assistant to the General Manager, with headquarters at Brunswick, Ga.

SYLVESTER MARSH, the inventor, projector and President of the Mount Washington Railway, died in Concord, N. H. on Dec. 30, aged 81 years.

WILLIAM LORENZ, late Chief Engineer of the Phila. & Reading R. R. Co., died of heart disease at his residence at Chestnut Hill, Philadelphia, on Dec. 29.

CAPT. DAVID NYE, General Superintendent of the North Pacific Coast Railroad, drooped dead in San Francisco, Dec. 29, of heart disease.

B. F. JONES, senior member of the firm of Jones & Laughlin's, of Pittsburgh, has been appointed President of the Iron & Steel Association, to succeed Daniel J. Morrell, resigned.

C. L. WILLIAMS is the newly appointed Superintendent of the Ohio River Railroad, succeeding Charles Howard. The Superintendent's office will be at Parkersburg, W. Va.

CHARLES H. WARREN, late Superintendent of the Humeston & Shenandoah R. R. died in Clarinda, Iowa, on Dec. 22. MR. WARREN was about 40 years old and was formerly Superintendent of the Wisconsin Valley and West Wisconsin Railroad.

LIEUT. HENRY O. HANDY, of the United States Navy, died suddenly at Tarborough, N. C., last week. He was a native of Massachusetts, and graduated from the Naval Academy in 1800. He was commissioned as Lieutenant in 1874 while serving on Coast Survey service, and afterward served for two years on the European station.

MR. LORENZ was born in Hanover, was educated at Gottingen and graduated with high honors. He came to America in 1848, and after some experience at teaching school, in 1850 entered the service of the P. & R. R. R. He was for many years Resident Engineer of the Lebanon Valley branch of the main line, with his headquarters at Lebanon, Pa. About 1870 he was made Principal Asst. Eng., under Chief Eng. Chas. E Byers, of the main line and all branches, and in 1871, upon the death of Mr. Byers, succeeded to his office. For the last year or two he has been Consulting Engineer, ill health having compelled him to relinguish some of the duties of the office of Chie Engineer.

MR. W. P. GERHARD, Civil Engineer, late Chief Engineer of the Durham House Drainage Company, having resigned his position with said Company has opened an office at 41 Dey Street, New York and offers professional advice and superintendence of construction in sanitary engineering works. While Assistant engineer to Col. Henry Flad in St. Louis, and later as principal assistant to Col. Geo. C. Waring, Jr., Mr. Gerhard has devoted special study and gained large experience in questions of water supply, sewerage and sewage disposal. He devoted the last four years in particular to the improvement of the sanitary condition of dwelling houses in city and country. His various reports and books on sanitary topics have been noticed from time to time in our columns.

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THE numerous changes required in our first ssue for this year, coupled with the awkward occurrence of a holiday, must be our excuse for any tardiness in publication or faulty make-up, in the present number. In another week we expect to have matters running more smoothly.

AFTER one year's experience the Improved Sewerage system of Boston, is reported as working without a hitch or flaw, and as realizing every expectation previously entertained. Among these expectations, however, was the one, held by its opponents, that it would nterfere with the general comfort of those residing on the borders of Quincy Bay. This also approaches realization, as the complaint is made that the stench is severe when the wind comes from certain quarters.

THE completion of the Mackay Bennett Cable is causing a decided ripple in the ocean cable pool. The rate has fallen to 40 cents per word, and Mr. John Pender, of the old combination, is devoting himself to maintaining this rate against any further attack.

As an indication of the influence of a rival in the field, the officials of the Globe Telegraph & Trust Co., with its £15,000,000 capital, usually curt, laconic and rude in their dealings with the public, are reported to have even condescended to crack jokes with their customers; a great condescension in them, and a wide departure from established custom.

Mr. Pender is reported to have already made overtures to the Mackay Bennett Co., to the end that they may work amicably together.

GROUND was broken for the new Croton Aqueduct on last Tuesday, at Shaft No. 24, near High Bridge. Division Engineer Watkins threw out the first shovelfull of earth.

THE Department of Engineering of the University of Wisconsin solicits, through a circular, drawings, lithographs or blue-prints of engineering structures and their details. This appeal to engineers and manufacturers is made in the hope of thus replacing the collection of plans destroyed by fire on Dec. 1. Assistance in building up the technical library is also requested, by the donation of spare papers on engineering, reports, etc. The circular is signed by Allan D. Conover, Prof. of Civil Engineering, and by Storm Bull, Prof. of Mechanical Engineering.

THE New York *Tribune* has an article on bad tenement houses in this city, or houses occupied by three or more families. Of the 23,000 tenements on Manhattan Island, 18,966 have more than one family on a floor; the remainder are the homes of well-to-do persons, and cannot be properly classed as tenement houses. Judging by the death rate in tenements; in 1878, 986 tenement houses had three or more deaths in them, two deaths were reported in 2,138 tenements and one death in 6,638 houses. This amounts to 53 per cent. of the total mortality exclusive of institutions.

According to the statistics of the 10th Ward, in 1879 it contained 999 tenement houses. Of these, 183 were rear buildings; 324 had from four to eight families; 272 from eight to twelve; 110 from twelve to sixteen; 192 from sixteen to twenty, and 62 tenement houses contained twenty or more families. The larger portion of these houses were thus occupied by not less than 50 individuals, and nearly 300 tenements contained from 70 to 100 persons.

MAJ. H. W. CLARKE, of the N. Y. and Penna. Boundary Survey, takes us to task for republishing the bit of news relating to the "Naming of Townships," in our last issue. We bow gracefully to the Major's superior knowledge upon this subject, and acknowledge that our scissors were in error when they snipped out that item.

Major Clarke further says that the Attorney General never had anything to do with township nomenclature; and that nearly all the townships were named forty years before the date mentioned in the article referred to. These were townships in the Military Tract, set apart for soldiers of the Revolution, and Surveyor General Simeon DeWitt determined, very properly, that they should have names of a military or heroic significance; but, to avoid possible jealousy and ill-feeling, he selected the names of warriors of ancient Greece and Rome. This accounts for the classical names abounding in Central New York.

Land townships, or the divisions of public lands, were generally numbered; naming was the exception. Those in the northern part of the State were named by the Land Proprietors. The town or civil divisions were named by the local authorities when organized.

M. LOUIS HEUZÉ, an architect of Paris, proposes as the latest scheme for rapid transit in that city, an elevated railway running through what he calls private ways. The type of elevated way he suggests is a series of ornamental cast iron arches, running one set across, and the other with the streets; for supports he uses cast iron columns. The road is double track, and he recommends its location upon streets cut through the centers of the building blocks, the new streets thus formed to be utilized, beneath the tracks, for pedestrians only and to be lined with shops and manufactories.

The chief argument in acquiring so expensive a roadbed is, that the line can be made more direct, avoiding the public monuments and squares; and that the lower way will afford a safe passage for pedestrians free from the dangers of the multitude of wheeled vehicles used in that city.

The plans and general location of the road proposed by M. Heuzé are displayed in *Le Genie Civil*, of Dec. 6. We will only say that the designs, while highly ornamental, are the work of an architect and not of a civil engineer.

Our Mathematical Column.

We begin this week the publication of a mathematical column which will appear throughout the year in the first number of each month. Mathematics, pure and applied, is the corner stone of all modern engineering. Anyone can build a road and bridge a stream, but without mathematics the construction would be expensive, ill adapted to its ends, or unsafe. Modern engineering is the art of training the forces of nature to the service of man so as to produce safe and durable structures at a minimum cost. The more close the competition the greater is the calculation required to meet this condition of minimum cost. Hence it is that engineers who can calculate and compute are apt to be the most successful. With more mathematics applied to their designing, the Ashtabula and Tay bridges would have been constructed to safely bear the heaviest trains and greatest winds, and would still be standing. With more preliminary mathematics many a railroad would be able to earn better dividends for its stockholders. No apology is therefore necessary in placing before our readers a subject in which they are all deeply interested. Our aim will be to make the column interesting by noting odd mathematical facts and processes, as well as useful by recording formulas and rules of practical value.

The Annual Convention of the Am. Soc. C.E.

Two weeks ago we commented on a circular issued by the American Society of Civil Engineers concerning the adoption of a new plan for conducting its annual conventions. The fact that a large number of members of that Society have been dissatisfied for some time with the annual convention is well known, as also the fact that a similar feeling exists in other similar societies. The opinion is widespread indeed that the annual convention needs to be reformed and conducted on a better plan. How that reformation is to be made, and what that new plan is to be, are now the subjects proper for discussion, and concerning them we here offer a few suggestions.

We lay it down as an axiom in the first place, that when a young man joins an Engineering Society he does so for the sake of improving and advancing himself in his profession. He does not seek thereby social pleasure, or moral improvement, but engineering associations merely. As an engineer he must do as engineers do. He must read what others write, he must learn how others think, he must inform himself regarding methods of investigation and details of construction. In listening to older and wiser men there is indeed a social pleasure and a moral improvement, but these can only be profitably experienced through the aid of professional subjects. The main object of an engineering society is in fact universally acknowledged by all to be the professional improvement of its members.

The annual convention, in order to be successful must therefore be planned with reference to this main object.

There are papers to be read; how shall they be arranged and read so as to produce the greatest professional improvement of the members? Discussions are to be held; how shall they be conducted so as to effect the greatest professional improvement? Excursions are to be taken; how can the maximum

professional improvement be derived from them? Opportunity must be given for rest and for conversation; how shall this be best arranged with reference to the main object?

For many recent conventions it has been a custom to appoint a local committee consisting of citizens of the city where the assembly is held, and that committee has virtually arranged the programme of the meetings and excursions. Consisting often of men who are not engineers and perhaps not members of the society, it could scarcely have been expected that such a committee could properly keep in view the idea of professional improvement. Excursions have hence been more prominent than meetings, and these have been largely of a social rather than of an engineering character. Lawn parties and receptions have been arranged, successful socially but unsuccessful professionally. The meetings for discussion have been few, short and in general not satisfactory. As a first step in the direction of reform it seems well to try the plan of abolishing the local committee, and allowing the officers of the society to arrange the programme and stand responsible for its success.

In order to make any programme successful it is necessary that it should be rigidly adhered to in all its details. If a meeting is appointed to begin at 9 A. M., let it be called to order promptly at that hour. As punctuality is one of the first laws of nature so should it be of the annual convention. Nothing could well be more depressing to the citizens of the city or to the members of the society than to find the first meeting of the convention opened an hour after the appointed time, as is too often the case.

It would be very desirable if the programme could be issued early, so as to be in the hands of members at least ten days before the date of the convention. To be of the greatest service the titles of the papers to be read at each of the meetings should be stated, and perhaps a brief abstract be given of the most important ones. In this way the minds of members could be prepared to better appreciate the papers themselves as well as the discussions which follow. As a matter of convenience it would be best also to group together the papers by subjects so that, for instance, those on hydraulics and river engineering might come the first day, those on railroads the second day, and those on bridge construction the third day. Under such an arrangement many members who find it difficult to be present throughout the entire session, might be able to attend for the one or two days when the discussion of the greatest interest to them occurs.

The reading of papers, unless judiciously controlled, is apt to become a dry and profitless performance. Everybody knows that it is impossible for an audience to follow a reader whose paper abounds with mathematical formulas or statistics or which is illustrated with complex diagrams. Such papers when in print may be of great value, but to read them is often an infliction which the audience is loth to endure. In the making up of the programme a careful censorship should be exercised that such papers only be presented by popular abstracts stating the salient points of the investigation. For a convention the bridge engineer must write so that the hydraulician can understand him, while the hydraulician must be able to state his argument so clearly that bridge and railroad experts can grasp the point. The length of a paper, too, is important; fifteen minutes is usually too long, and often five minutes will be enough. When the paper is printed let it be condensed so as to be short and terse. During the first five minutes an audience is attentive, during the second it is indulgent, and during the third it often becomes impatient. A pointed and suggestive paper of five or ten minutes duration will greatly interest and impress the audience and call forth an animated discussion, while one of greater value but greater length often fails in producing an effect. It would be proper that the programme should state the number of minutes required for the reading of each paper.

The discussions are often the most interesting and profitable part of the exercises and should hence be encouraged. Mankind naturally enjoys discussion and debate. By it conflicting opinions are balanced, different methods of practice are compared, and a clearer understanding is attained, of the subject in hand. Subjects of a semi-popular character like standard time, metric system, and technical education have often called forth debates of great interest. It seems well therefore that in selecting the topics for consideration those which are the most likely to elicit discussion should receive the preference.

The excursions need to be arranged and conducted with great care. Too often has it happened that members have been dragged out of bed at an unseemly hour of the morning, carried for hours in a tedious railroad ride to see something of little engineering importance, and returned almost exhausted at a late hour of the evening. The objects visited should be of real engineering interest in order to render the excursion of the greatest professional benefit, and arrangements should be made that a careful explanation of all technical features should precede or accompany the visit of inspection. Half a day seems the maximum length of time required to render an excursion successful; if this be exceeded pseudo-engineering is sure to predominate, and fatigue renders real interest impossible.

In order to make the social features of the convention satisfactory they should be subordinate to the real professional work. If excursions and receptions are numerous the meetings are sure to be lifeless and poorly attended. Man cannot serve two masters, nor can he sit upon two stools at one and the same time. Work first and play afterwards, and more work than play,—these are laws which nature has established in order to render this terrestrial life enjoyable. The main business of the convention is professional discussion and improvement, and all social arrangements should be subordinated to this. Then will the excursions be truly appreciated and the convention long be remembered as a success.

The annual convention usually begins on a Tuesday and continues three or four days. In the following suggestion for a programme of exercises three days have been adopted. On Tuesday promptly at 10:00 A. M. let the convention meet, organize and be welcomed by the local authorities. Then the reading of papers and discussions upon railroad construction and operation might follow until 1:00 P. M. The afternoon session from 3:00 until 6:00 could be specially devoted to a debate and discussion upon one or two subjects of general interest, such as the compressive strength of wrought iron or the use of the pnuematic system for constructing tunnels. The evening of Tuesday would be left for social converse and rest. On Wednesday from 9:00 until 1:00 a session for the reading of papers and discussions upon designated subjects would be held, while the afternoon might be left free for excursions and for seeing the city. On Thursday the morning session would be devoted to the reading of papers, and the afternoon session to receiving the reports of committees and to discussions concerning the business and policy of the society. On Thursday evening the annual address of the President, followed by a reception or promenade, would form a fitting conclusion to a profitable and successful convention.

THE Lidgerwood Manufacturing Co., of New York, has been awarded a Gold medal by the Massachusetts Charitable Mechanic Association, of Boston, for superior excellence in Hoisting Engines, Boilers and Small Stationary Engines.

Report of the Secretary of War.

The report of the Secretary for 1884, issued November 21, states that the total appropriations for the fiscal year ending June 30, 1885, was $45,570,551.53; of this sum, $15,687,485, was devoted to public works, including river and harbor improvements. The estimates for the year ending June 30, 1886, are $50,850,500.58; $18,497,460.48 being set aside for public improvements with the new sea-coast fortifications included therein.

The report of the Chief of Engineers has already been commented upon. In the report on the Improvement of the South Pass of the Mississippi River, it is stated that from September 10, 1883, to September 9, 1884, four quarterly payments for maintenance, amounting to $100,000, and two semi-annual payments of interest on the $1,000,000 retained, amounting to $50,000, have been made to Mr. Eads. The total expenditure for this improvement, to the last date given is $5,000,000. In referring to the Ordnance Department the Secretary hopes that Congress at its "next session" will appreciate the pressing needs of the Department and the difficulties under which it now labors in attempting to secure suitable material for gun construction. The steel makers of the country will not undertake the production of steel on a scale adequate to the wants of the War Department without the inducement of being fairly remunerated for their outlays. Speedy action on the part of Congress is all the more necessary when it is considered that at least two years must elapse, even after ample encouragement has been afforded, before the requisite plant can be designed, constructed and set into operation. Two years more will then be required to manufacture and test experimental or typical guns before the manufacture in quantity can be proceeded with.

Pending the action of Congress, the Department is proceeding with the conversion of 10-inch smooth-bore guns into 8-inch rifles, by lining either with a coiled wrought-iron or a forged steel tube; fifty guns will thus be converted within the year. In the fortification bill of July 5, 1884, $15,000 was appropriated to be used in experiments with dynamite or other high explosive projectiles. The Department has given all proper assistance and encouragement to private parties having designs or inventions that promised success; but the trials so far, have been merely tentative, and nothing has been developed demanding special mention. Experiments have also been made in firing shells charged with explosive gelatine from service guns. The practicability of firing such shells, with ordinary gunpowder as a propelling agent, seems now almost assured. Some 8-inch steel shells have been ordered with a view to increasing the penetration in iron plates, with the expectation that the explosive effect of the gelatine will be thereby augmented.

The Chief Signal officer reports that the total expenses of his department, for the year ending June 30, 1884, was $958,392.95, from which should be deducted $17,074.72 received from the military telegraph lines. The appropriation for 1885 is $1,001,228.93, and the estimate for 1886 is $1,552,659.84. Secretary Lincoln does not concur in a recommendation for an increase in the appropriation submitted. He gives his reasons as follows:

"My reasons are briefly that, even if in the Army bill the amounts to be expended for the Weather Bureau should be made specific and definite, as was not the case until recently, I deem it prejudicial to the interests of the Army that its apparent cost of maintenance should be so largely increased by adding to it the cost of the Weather Bureau service, with which the Army is not concerned. It would seem to be as appropriate to make the river and harbor appropriation a part of the Army expenses be-

cause a few Army officers supervise the work. In this connection, I renew my recommendation that the temporary legislation of the last two years, forbidding the expenditure for this service of money not specifically appropriated therefor, be made permanent legislation applying to all future appropriations to be disbursed by the Secretary of War."

The points of difference between the Secretary and the Chief Signal Officer as to the ill-fated Greely Arctic Expedition have been already sufficiently commented upon in the daily press.

The Water Jet in Pile Sinking.

A correspondent, and a former officer of the corps of U. S. Engineers gives us the following sketch of the discovery of the value of a water jet in sinking piles in sand:—He says, that Capt. Walter H. Stevens, U. S. Engineers, and afterwards a Brigadier General in the Confederate army, was engaged in constructing an iron lighthouse, in 1859 or 1860, near Galveston, Texas. The platform carrying the plant for sinking the screw piles, intended for the foundation, was wrecked by a storm, and the mass of iron work was soon firmly imbedded in the quicksand beneath.

Capt. Stevens, in the attempt to recover his lost material, donned a suit of submarine armor, and went down to study the effect of a jet of water from a pump in loosening the buried members of the lighthouse. He soon discovered that he himself was firmly anchored in the quicksand and on applying the jet to his feet, with the intention of freeing himself, in a second of time was buried to his waist. His situation was an awkward one, but by signalling to his men to hoist, and at the same time stirring up the sand with the jet, he was happily rescued.

The experience was not lost upon the Engineer, and shortly afterwards he successfully applied the jet action in sinking piles in sand. The Confederate officers, under the direction of Col. S. H. Lockett, Chief Engineer of the department of the Gulf, C. S. A., in this manner filled the Bay of Mobile with obstructions, sinking trunks of trees, 3 ft. in diameter and sharpened at both ends, into the sand and firmly anchoring them there by the use of a jet from a common fire engine on a steamboat, The piles were planted from 12 to 20 ft. deep. and they settled in the sand at the rate of 12 in. per second under a jet from an 1¼ in. nozzle on a 3½ in. hose. The nozzle was held by two staples down near the point of the pile, and was secured there by a small rope passed through the staples. 5,000 piles were thus put in.

Engineer Society of Western Pennsylvania.

At the regular meeting of Dec. 16, Prest. Miller in the chair and forty-four members present, a report was read by Mr. Lindenthal on the subject of publishing the proceedings of the society with the "Association of Engineering Societies". After detailing the organization of the Association, the expense to members and the advantages of such publications, the committee recommended the joining of the Association. On motion the report was accepted.

The Committee on nominations presented the following names of officers to be voted for at the annual meeting:—For President, Geo. H. Browne; for Vice President, C. L. Strobel; for Directors, Wm. Martin, Wm. Thaw, Jr.; for Treasurer, A, E. Frost, and for Secretary, Jas. N. Harlow.

Mr. John A. Brashear read a paper on "Critical Methods of Detecting Errors of Plane and Spherical Surfaces."

EXPERIMENTS have been made with the pulp of the Floriday banana, and the result is that from it can be obtained a splendid quality of paper and rope.

Sureties of the Contractors for the New Croton Aqueduct.

The following names and amount of sureties are obtained from the official records of the Aqueduct Commissioners:

CONTRACTOR.	SECTION.	SURETIES.	AMOUNT.
Heman Clark.	A	Cornelius H. Delemater, New York Samuel D. Coykendall, Kingston	$250,000
	B	Timothy J. Sullivan, Albany Erastus Wiman, New Brighton Jas. Wm. Hinkley, Poughkeepsie	270,000
O.Brien & Clark.	9	Thomas Cornell, Kingston Geo. H. Robinson, New York Jas. L. Williams, Poughkeepsie Maurice B. Flynn, New York	320,000
	8	Thomas Cornell, Kingston Edward Kearney, New York	280,000
	7	Lewis Rider, Rhinebeck Thomas Cornell, Kingston R. P. Huntington, Rhinebeck	330,000
	6	Samuel D. Coykendall, Kingston Charles H. Field, New York Maurice B. Flynn, " "	140,000
Brown, Howard & Co.	2	Calvin S. Brice, " " Samuel Thomas, " " Fred'k A. Brown, " "	1,266,000
	4 & 5		

The sureties are in double the amount of the security required of each contractor for the performance of his work.

Official Organization of the New Croton Aqueduct Commission.

The organization for the construction of the New Croton Aqueduct, as given below, is official and includes all appointments at the present date, excepting those of lower grade.

THE AQUEDUCT COMMISSION:
The Mayor of New York.
The Comptroller of New York.
The Commissioner of Public Works.
C. C. Baldwin.
James C. Spencer.
William Dowd, *Commissioners.*
James W. McCulloh, *Secretary to the Commission.*
Joseph P. Davis, *Consulting Engineer.*

CHIEF ENGINEER'S OFFICE.
Benjamin S. Church, *Chief Engineer.*
Alphonse Fteley, *Executive Engineer.*
Frederick S. Cook, *in charge of Draughting Bureau.*

FIELD STAFF:
H. S. Craven, *Engineer of Construction.*

Charles S. Gowen,	Engineer	1st Div.	Croton Dam.
John B. McIntyre,	"	2nd "	Sing Sing.
John M. Wolbrecht,	"	3rd "	Tarrytown.
Alfred Craven,	"	4th	Irvington.
E. Sherman Gould,	"	5th "	Yonkers.
Frederick W. Watkins,	"	6th "	24th Ward.
Edward Wegmann, Jr.,	"	7th "	Manhattan Island.

Detailed at office of Chief Engineer.

H. S. Craven has general charge of all construction in the field, and each division engineer will have under him an assistant engineer and an ordinary instrumental corps. Mr. Frederick S. Cook, in charge of the draughting department at the main office, has rank of division engineer.

The Railroads of Minnesota.

Gen. J. H. Baker, in the fourteenth annual report on the railways of Minnesota, soon to be issued, presents in an exhaustive manner the present condition of railway affairs in that State. The report is too voluminous to review in its entirety; so we only mention it as a model of its kind, and give some of the statistics and remarks contained in it.

There are now $4,162\frac{23}{100}$ miles of railway in the State, only $256\frac{84}{100}$ miles having been built in 1884 to Dec. 1. The total cost of all this road operated to June 30, 1884, was $161,054,515, the average cost per mile being $40,994.56.

The gross earnings of all lines operated in the State to June 30, 1884, were $80,864,301.94.

The gross earnings in Minnesota for year ending June 30, 1884, were $23,243,466.22.

The number of passengers carried by all lines operated in Minnesota to June 30, 1884, was 17,873,892.

The number of passengers carried in Minnesota for year ending June 30, was 5,962,297.

The average distance traveled by each passenger on all lines operated in this State to June 30, 1884, was 42.7 miles.

The average distance traveled by each passenger over Minnesota lines was 38.4 miles.

The average earnings on each passenger over all lines operated in this State to June 30, 1884, was $1.16.

The average earnings on each passenger in Minnesota for the year ending June 30, 1884 was $0.93.

The average rate per passenger per mile in Minnesota for year ending June 30, 1884, was 2.73 cents.

The average gross earnings per mile of railway in the State for year ending June 30, 1884, were $5,924.777

The average cost per mile of operating the railways of Minnesota for year ending June 30, 1884, was $3,004.28.

The operating expenses in Minnesota for year ending June 30, 1884, were $11,784,253.58.

The operating expenses of all lines operated in Minnesota for year ending June 30, 1884, were $45,515,003.67.

The average percentage of operating expenses to gross earnings was 50.69 per cent.

The amount paid in addition to operating expenses on entire lines was $59,354.56.

The taxes paid on all lines operated in Minnesota for year ending June 30, 1884, were $2.169,584.22.

The taxes paid on lines in Minnesota for year ending June 30, 1884 were $645,735.18.

The number of tons of freight carried in Minnesota for year ending June 30, 1884, was 8,516,178.

The average amount received for each ton of freight handled during the year was $1.94.

The number of employes on all roads operated in Minnesota for the year ending 30, 1884 was 58,513.

The number of cars of all kinds used by the companies operating in the State for the year ending June 30, 1884, was 69,270.

Number of engines used by all roads operating in State for year ending June 30, 1884, was 2,275.

The construction account for the year for all lines operated in the State was $20,044,742.51.

The number of acres of land sold by all lines for the year was 468,520.65.

The amount received by railway companies during the year for land was $1,991,901.27.

The number of acres sold to June 30, 1884, by all companies was 3,355,867.65.

The amount received for lands sold to June, 30, 1884 was $14,793,087.96.

The number of miles of steel rail track in Minnesota is 2,518.22.

The number of miles of fencing in the State is 3,146.6.

Elevator capacity in Minnesota at close of year ending June 30, 1884, 25,739,700 bushels.

RENEWALS AND REPAIRS OF TRACK.

	Quantity.	Amount.
New steel rails, costing in track	19,989 tons.	$849,214.29
Equal to miles of main and side track	202 miles.	.....
Rerolled iron, costing in track	5 tons	218.74
Relaid rails, costing in track	5,694 tons	190,795.47

Equal to	63 miles.	
Total miles of iron and steel rails laid	265 miles.	
Iron and steel rails repaired at rail mills	42,096 rails.	
Cost of repairs at rail mills		9,149.37
Total number of new track, switch and bridge ties, costing in track	1,072,465 ties.	520,326.08
Average cost	34.29 cents.	
Average cost in track	49.52 cents.	
Equal to	383 miles.	
Cost of raising track to grade, and for ballasting on the several lines		207,844.09
Cost of deepening and widening ditches		87,660.60
Standard splice bars and bottom plates	26,505 numbers.	8,928,32
Angle splice bars	179,793 numbers.	45,847.43
Spikes	5,963 kegs.	20,779.41
Bolts	2,630 kegs.	15,845.21
Nut locks	458,363 numbers.	9,246,67
Switches	229 numbers.	5,779.12
Total		$1,981,634.83

RENEWALS OF FENCES, ETC.

	Quantity.	Cost.
Posts	122,587 posts.	$8,680.73
Nails and spikes	837 kegs.	2,621.14
Cr ssing planks	983,344 feet.	14,746.37
Fencing	973,595 feet.	9,603.40
Barbed wire fencing		29,303.29
Total		$64,954.93

The portion of the report relating to the Nothern Pacific R. R. is very full and the length of road operated by this company at the end of the fiscal year is given as follows:—

	Miles.
Duluth to Northern Pacific junction (owned in common with St. Paul and Duluth railroad company)	23.2
Northern Pacific junction to Wallula junction	1,650.5
Northern Pacific junction to Superior City	23.5
Superior City to east end of track	20.5
Portland to south bank of Columbia river, opposite Kalama	36.3
Kalama to Tacoma	105.1
CASCADE BRANCH.	
Tacoma to South Prairie	25.0
From Columbia river up Yakima valley	25.0
Main line and Cascade branch	1,915.1
From Puyallup junction (10 4-10 miles east of Tacoma,) to Stuck junction (the junction with Puget Sound Shore railroad	6.93
From South Prairie to Ca. bonado and Wilkeson and South Prairie coal fields	8.7
Whole length of road owned by Northern Pacific railroad company	1,930.73
LEASED.	
St. Paul & Northern Pacific railway, Brainerd to Minneapolis	127.1
Trackage. Minneapolis to St. Paul (St. Paul, Minneapolis & Manitoba railway)	11.36
	2,069.19
BRANCH ROADS.	
Little Falls & Dakota railroad	87.85
Northern Pacific, Fergus & Black Hills railroad	117.10
Fargo & Southwestern railroad	87.40
Sanborn, Ceoperstown & Turtle Mountain railroad	36.50
Jamestown & Northern railroad	64.10
Skyeston branch	12.90
Rocky Mountain railroad of Montana	51.70
Helena & Jefferson County railroad	20.10
	477.65
Total length of road owned and leased at the end of the fiscal year	2,546.84

The sections of road from Portland to a point on Columbia river opposite Kalama 36 3-10 miles, and from Columbia river up Yakima valley 25 miles, and from Superior City to the east end of track, 26 5-10 miles, have not been operated.

Construction is progressing on the Wisconsin division between the east end of the track and Ashland, 36 miles, and on the Cascade division from the west end of the track in the Yakima valley to Yakima City, 57 miles.

The total expenditure for equipment of the Northern Pacific R. R., including 182 locomotives, is $5,594,672.49. Improvements and betterments, to date have cost $866,058.06.

Gen. Baker condemns the railroad code of the State as the most meagre and defective of any northern State, recommends an official railway map; and criticises the local passenger rate of four cents per mile as being too high, the average passenger rate being $2\frac{71}{100}$ cents per mile.

He reports the average cost of operating roads within the State as showing a decrease of 5 per cent.; the freight business has increased, for the year, 8 per cent., and the passenger business 10 per cent.

ENGINEERING NEWS for three months One Dollar.

TRACK.*

BY W. B. PARSONS, JR., C. E.
ROADMASTER SUSQUEHANNA DIVISION ERIE R. R.

(*Continued from page 296. Vol. 12.*)

The class of chair joints has been improved in several ways, the best of which improvements are contained in the Fisher joint.

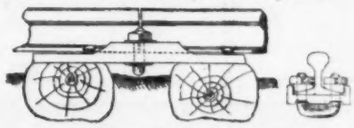

Fig. 35—THE FISHER JOINT.

Its advantages are that it is a suspended joint and has its material distributed economically, since it is all at the bottom of the rail thus virtually adding to its depth; it moreover gives support to the whole end of the rail which cannot deflect until the chair does. The Fisher joint is held by a much larger bolt than can be safely put through the web of a rail and therefore permits the nut to be screwed down with greater force. This vertical bolt also prevents creeping since the rails butt against it, the corners being drilled off to receive it.

This joint like all chair joints, or any other which like them in part or whole lies between the rail and tie has one great disadvantage. The joint ties must be cut down, giving a tendency to split and extra liability to rot, or else they must be lowered. If they are lowered it is done by inclining them (unless the joints are "opposite"), when the surface of the ties and that of the rail base are no longer in parallel planes giving the joint uneven bearing. Secondly all chair joints are noisy. It is impossible to keep track in such shape that the rail will not rattle in the chair especially after wear. The first step in advance over the old-fashioned chairs was the Fish-plate which began to come in general use in 1847. Two straps of iron bolted to the rails. as in Fig. 36. and receiving its name from the sailor's term of "fishing" a joint on the same principle. They vary in length from 15 to 20 inches, in height according to rail section and in weight from 8 to 14 lbs. a piece. They are held by 2, 4, or 6 bolts, generally 4. The spacing of these bolts follows no rule but varies arbitrarily with each road. Such a joint can be either suspended or supported but unless the plates are very heavy and traffic light it is best to use them supported. The metal is not well distributed to give much vertical strength and if they have to carry weight, as in a suspended joint, they will break. To prevent this breaking a plate reinforced in the center called the Samson bar, has been invented. To prevent creeping with the Fish-plate joint the corner of the base is cut away sufficiently to hold a spike or else back from the end a proper distance in case a suspended joint is required. Sometimes however, instead of cutting away the corners, slots are punched about 2 inches back from the end so that there is room for the slots of both rails on the same tie.

This gives 4 spikes instead of 2 to the joint.

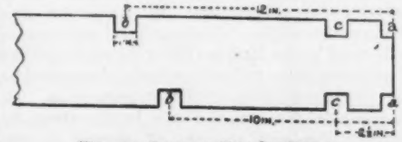

Fig. 37.—SLOTS IN BASE OF RAILS.

Fig. 37 shows the three styles marked respectively a, b, c,. If a rail is spiked in warm weather, the spike must be driven on that side of the slot away from the end of the rail thus allowing the rail to contract and expand, though in narrow limits. In order to give a plate joint sufficient strength to act as a suspended joint an angle bar weighing from 15 to 20 lbs. a piece instead of a straight bar is used as shown in Figs. 38,* and 39 the standard joints of the N. Y. L. E. & W. R. R. & P. R. R. respectively. Such a joint, varying only in details of size of plate and spacing of bolts, is the generally adopted standard of the day and hence claims our attention at length.

The first advantage over the straight splice is obtained by having the increase of metal at the bottom adding to its vertical strength and thus justifying its use as a suspended joint. Again the strength of the joint is materially increased laterally, for rails have not only to resist vertical but lateral strains as well and on a curve, unless they are carefully bent previously, they tend to straighten and obtain the amount of curvature by deflecting at the joints. This tendency is counteracted by the lateral stiffness of the angle bar. Furthermore as the bottom of the angle is turned over the base of the rail it gives an increased bearing on the ties and, what is a still greater advantage, permits the plates to be spiked independently of the rail. In both the chair and fish-plate joints the rails are held from creeping by spikes driven in slots in the rails themselves, which is a great mistake. When the rail has expanded or contracted until it is fast against the spike any further movement must be obtained by crowding the spikes. If a rail is to be spiked in a slot it should be at the center. All this is obviated in the angle plate, the slot being cut in the flange of the angle. Now, while each rail is free to contract and expand to the limit, the string of rails as a whole is firmly held against creeping or runing. These spikes morover hold the plates in place even after the bolts loosen. Hence we can sum up its advantages:—First; increased vertical and lateral strength with elasticity retained. Second; suspended joint. Third; track is held from creeping although each individual rail is allowed to expand freely.

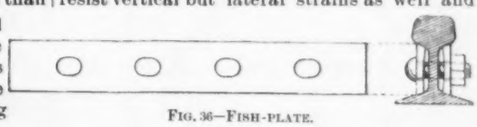

FIG. 36—FISH-PLATE.

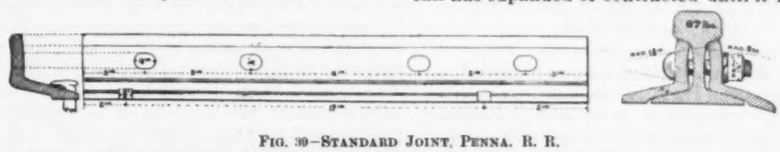

FIG. 39—STANDARD JOINT, PENNA. R. R.

(TO BE CONTINUED.)

THE introduction of arms of precision of long range, and capable of being fired at a rapid rate, has it is well known, greatly reduced the percentage of wounds inflicted by the bayonet in recent wars; but it has not hitherto accurately ascertained how large that reduction has been. From statistics, derived from a competent German source, on the proportion of such wounds in the wars of the last thirty years, it appears that in the Crimean war it was 0.41 per cent., and in the Italian campaign of 1859, 0,23 per cent. In the Danish war of 1864 it fell to 0.08 per cent., and as low as 0.03 per cent, in the Austro-Prussian war (1866). It rose again to 0.08 per cent. in the Franco-German war (1870-71), and it was only 0.08 per cent. in the Austrian campaign of occupation in Bosnia in 1878. No details are furnished with regard to the last Russo Turkish war (1877-78).

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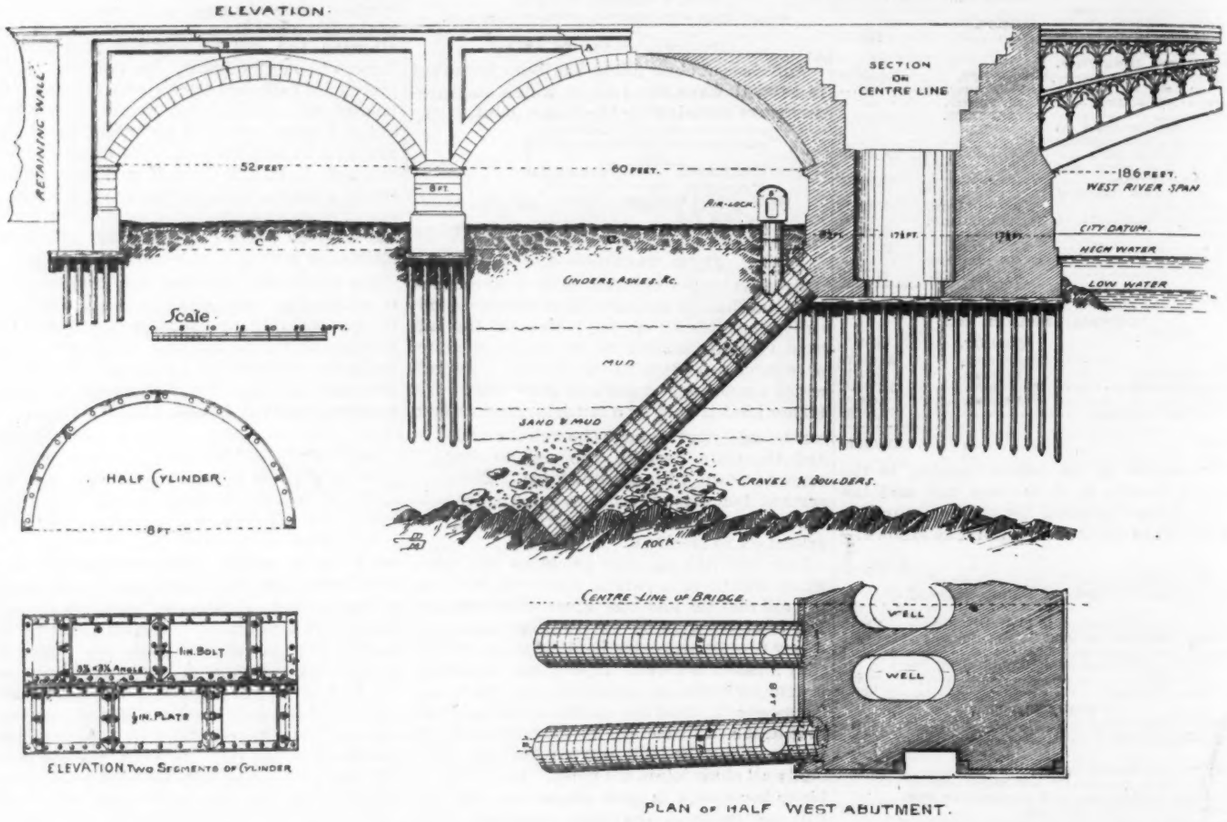
* For Fig. 38 see next issue.

FIG. 1.---REPAIRS TO CHESTNUT STREET BRIDGE, PHILADELPHIA.



Repairs to the Chestnut St. Bridge in Philadelphia, Pa.

The repairs which form the subject of our illustration and are now in progress, involve a novel application of the use of compressed air, and are consequently interesting as opening up further possibilities in the employment of this rather new agent in engineering construction.

That the necessities of the case may be better appreciated, it is necessary that we enter into a short sketch of the structure it is thus intended to strengthen. The Chestnut St. Bridge crosses the River Schuylkill, in Philadelphia, by two graceful iron arched spans of about 185 ft. each; with two arches of masonry on the west bank of the river, as shown, and continues thence westward by two retaining walls, carrying the western approach, which is about 390 ft. long.

The material upon which this entire west end of the bridge is founded is a soft alluvial deposit some 45 ft. deep to the bed of gravel and boulders overlying the rock. It is practically soft mud, affording little or no resistance against a horizontal force. The foundation is on piles, and in the case of the piles supporting the approach walls there were no ties connecting the foundations of the two parallel walls together. As a consequence of this latter omission, as soon as the heavy material forming the approach was dumped in upon the soft substratum, the heads of the two distinct lines of piles were pushed outward. They, of course, carried with them the platform and the walls above, and the result was a serious bulging of the approach and the consequent weakening and cracking of the extreme west arch abutment. Buttresses were built against the walls, and matters left to take care of themselves for awhile.

But the trouble continued and further cracks and settlement warned the authorities that some radical action was necessary. Holes were now drilled through the abutment at the east end of the approach wall and very heavy iron tie-rods were inserted to prevent any further spreading; but the surfaces held in place by the rods and their plates were so small when compared to the total area affected, that little good resulted from this expedient. As the west main abutment now developed a westward tendency and with a consequent tipping of the pile heads under it, an attempt was made to arrest this movement by putting in the heavy timber struts, shown at C. C. These were built beams, 36 in. deep and 12 in. wide each, and placed 6 ft. apart, between centers. This plan also failed to accomplish its intended purpose. In this emergency, Mr John F. Anderson, of the firm of Anderson & Barr, engineers and contractors, suggested to the city authorities the use of iron cylinder struts, extending from the foundation masonry of the west main abutment to the bed-rock, and thus disposing at once of the mischief-making thrust. Plans were accordingly adopted from his designs, and at the letting, the firm, of which he is a member, obtained the contract and are now carrying it to completion. Mr. Anderson was the inventor of the "pilot tunnel," so successfully used in the Hudson River Tunnel, and the experience there gained no doubt suggested to him the possibilities of the present plan. In all essential features the tube is the same, in construction and manner of placing it, excepting that instead of running forward horizontally, he now proposed to descend on an angle of about 45° to the bed rock.

The cylinders used are 8 ft. in diameter and about 65 ft. long each. They are built up of ½ in. wrought-iron plates, each plate 2 ft. wide and about 3 ft. long, eight plates being required to complete a segment of the cylinder. Around the edges of each plate, as shown in the illustration, are riveted 3½ × 3½ in. angle irons, and the abutting limbs of these angles are drilled for the reception of 1 in. bolts; five bolts in each horizontal and three in each vertical joint. These plates are so bolted together in forming the cylinder that they "break joints."

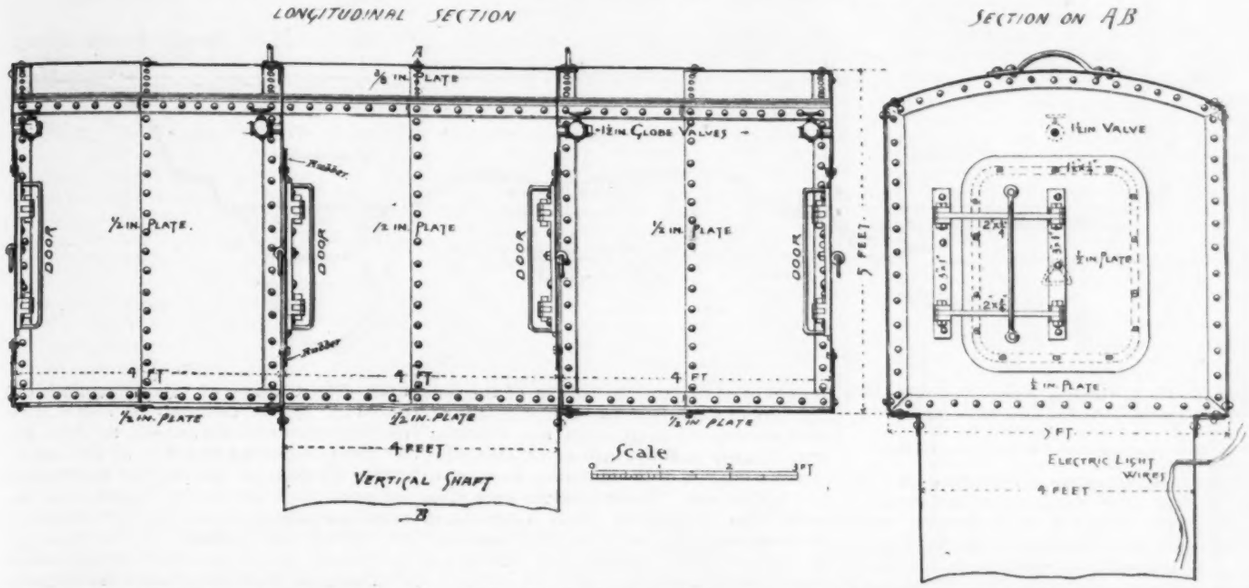
The material being prepared and the air-compressing plant set up, work was commenced on the first cylinder as follows:

At a point just outside of the abutment masonry and nearest the southwest corner, a pit was dug to the water line, and in it was built up the 4 ft. vertical shaft which was intended to connect the inclined strut with the air-lock. The bottom of this tube was so shaped as to fit the convexity and angle of the main cylinder. The air-lock, to be further described, was now put in place, and all pipe connections being made, the workmen were ready to begin upon the task proper. In this case the material was, at the beginning, sufficiently stable to permit several of the rings to be fitted without interference from water; after that, the plates were carried through the air-lock, and bolted into position as the soil was removed; the top-plates first and then regularly around the cylinder. Work was carried on with about three rings at a time, so as to keep the working face as nearly horizontal as was possible. The excavated material was removed through the air-lock in canvas bags in the manner usually adopted in the pneumatic process.

When the boulder stratum was met the larger rock had to be broken up and removed and the sticky mud of the upper stratum was freely used in stopping all leaks in the joints between the plates, which, being made as they were of ordinary angle irons, were by no means tight. This answered the purpose however, admirably as it so often did in bad spots in the Hudson Tunnel.

When the rock was finally reached with this first column, this was cut so as to afford a continuous inclined face to the strut, and the entire column was filled with concrete up to the top. We should here remark that the bottoms of the two outside cylinders deviate, by about 2 ft., from a line parallel to the axis of the bridge; in other words, they spread to that extent. The column being filled, the connection between this strut and the foundation masonry is made by carefully stepping off both the cylinder and the masonry, filling in

FIG. 2.---REPAIRS TO CHESTNUT STREET BRIDGE---AIR LOCK



between with concrete in such manner as to make the foundation continuous at that point. Four of these cylinders will be used disposed as shown in illustration.

The air-lock is also especially designed for this work, but can readily be used elsewhere as it is intended to form a part of a regular contracting plant. The lock is 5 ft. square in section, with a rounded roof, and is 12 ft. long, divided by two inside partitions into three equal parts. Doors are placed in all four walls, so that it is actually a double lock permitting entrance from either end. The doors themselves are 36 × 31 in. and make an air-tight joint by means of a continuous washer of rubber secured by an 1½ × ¼ in. iron band bolted to the door, which is made of ½ in. plate iron.

The hinges of these doors are deserving of a special mention, being so designed as to permit a ready and even pressure from the compressed air upon the surrounding rubber washer, and thus insure a tight fit between the door and the lock wall. To this end the door is hinged at the middle as shown, instead of to one side as is usual.

In filling the cylinders with concrete, this double air-lock proved very serviceable. The concrete was passed into one lock as it was being removed from the other; the supply was thus continuous and almost equalled in volume that sent in by an ordinary supply shaft. When the concrete reached the central lock it was shovelled down a tube in the vertical shaft and then by an open trough it passed to the bottom of the of the 8 ft. cylinder and was distributed and packed.

The cutting out of the masonry in the main abutment and the refilling with concrete was very nearly all done under air-pressure. Four feet of the vertical shaft, leading to the air-lock, is left finally in place and is filled with concrete.

The interior of the cylinder, as well as the compressor house, is lighted by the incandescent Edson electric light, wichh is advantageous in furnishing the maximum of light with a minimum of heat, a very important consideration to the worker in compressed air. At this date one cylinder is in place and filled and the second one is being completed. We will note any further development of this interesting work as it may occur.

MM. H. FOL and E TARASIN have ascertained that sunlight penetrates the waters of the lake of Geneva to a depth of 170 meters, where the luminosity is about equal to that of a clear, moonless night.

Nebraska Engineers and Surveyors.

The Second Meeting of the Nebraska Association of Engineers and Surveyors will be held at the County Surveyor's office, (247 South 11th street,) Lincoln, Nebraska, beginning at 4 o'clock P. M., Tuesday, January 13th, 1885.

Several papers will be read and a full discussion had of interest to Engineers and Surveyors.

These, together with the opportunities for meeting old acquaintances, as well as new ones, will make the meeting a pleasant one for all.

Certificates for round trip tickets at one and one-fourth fare, over the Burlington & Missouri River and Union Pacific Railroads, can be had by making application to the Secretary before time of starting.

J. P. Walton, County Surveyor, Lincoln, Neb., is the Secretary.

Connecticut Civil Engineers and Surveyors Association.

The First Annual meeting will be held at the rooms of the Stationary Engineers Association, 87 Church Street, New Haven, Tuesday, January 13th, 1885.

Headquarters at the Tontine House, Church Street, opposite the Public Square. The programme is as follows:

10 A. M.—Business meeting. Annual reports. Election of new members. Election of officers for the ensuing year, amending constitution etc. 2 P. M.—Discussion of the following topics: 1. New England Rural Land Surveying. Opened by a paper presented by W. E. Pettee of Lakeville. 2.—Dams. Opened by a paper to be presented by B. H. Hull of Bridgeport. 3.—Staking-Out Frogs and Switches. Opened by notes to be presented by William G. Smith of Waterbury. 4.—Transit surveying. Opened by practical suggestions on the subject by E. P. Augur of Middletown. 5.—The Bristol Water Works. Described by R. D. Barnes of Bristol.

7 P. M.—Discussion of the Sewer Appurtenances in use in different parts of the State, by C. A. Ferry of New Haven, C. H. Bunce of Hartford, F. F. Weld of Waterbury, E. P. Augur of Middleton, William B. Ryder of South Norwalk, H. S. Whipple of Birmingham, C. E. Chandler of Norwich, and others.

Arrangements for reduced rates at the Tontine House have been made, and it is hoped as it is expected, that there will be a large attendance at the meeting. Those intending to be present at the meeting should address as early as possible, D. C. Sandford, Asst. Secretary, New Haven, Ct.

The officers of the Association, are *President*, B. H. Hull, Bridgeport; *Vice Presidents*, A. W. Rice, New Britain, H. J. Kellogg, Waterbury; C. E. Chandler, Norwich, D. C. Sandford, New Haven; *Treasurer*, D. S. Brinsmade, Birmingham; *Executive Committee*, B. H. Hull, Bridgeport, C. H. Bunce, Hartford, E. P. Augur, Middletown, C. M. Jarvis, East Berlin, N. J. Welton, Waterbury; *Committee on Membership*, T. H. McKenzie, Southington, H. G. Loomis, Hartford, Sylvanus Butler, New Haven.

Indiana Surveyors and Engineers.

The Fifth Annual Meeting of the Association of County Surveyors and Civil Engineers of Indiana, will be held at the office of the County Surveyor, at Indianapolis, commencing at 2 o'clock P. M., Tuesday, January 20th, 1885.

The subjects of Land Surveying, Drainage, Gravel Roads, Bridges, and other important subjects will be discussed.

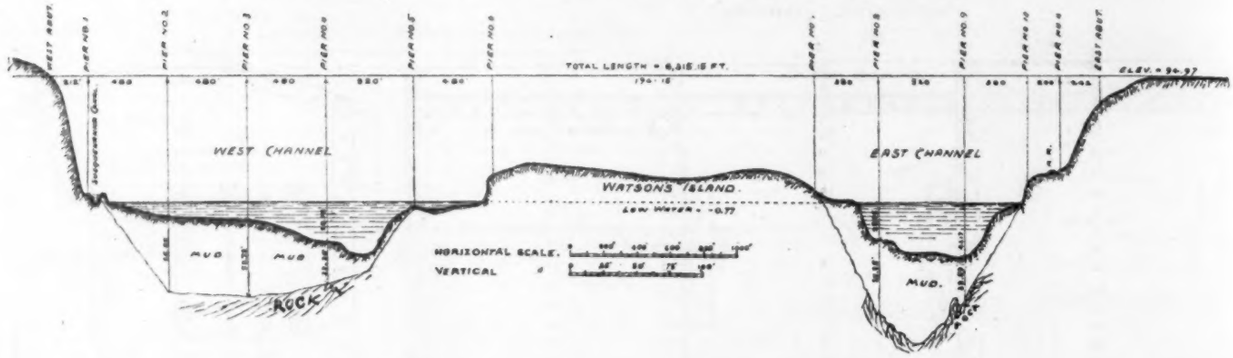
The Legislature will be in session, with strong probability of some radical changes in the laws relating to Drainage, Gravel Roads and Surveyors' duties. The fee bill will, doubtless, also be overhauled.

Commissioners of Drainage, Manufacturers of Engineers' Supplies, Bridge Builders, Contractors, and all others interested in the profession are cordially invited to attend and bring anything that will be of interest.

Lewis S. Alter, C. E., of Remington, Ind., is Corresponding Secretary.

THE project of constructing a storm sewer for the relief of what are known as "the flooded districts" in Brooklyn, at a cost of nearly a million dollars, has been abandoned, at least for the present. The Corporation Council, in a long opinion furnished to the Board of Aldermen on the subject, while holding that the money raised by city bonds, before the constitutional amendment limiting the indebtedness of cities goes into effect on the 1st of January, could be used to complete the work of building the sewer, fears that a different interpretation might be put upon the law by the courts, and that complications might arise therefrom which he deems it safest to avoid. The whole subject was thoroughly discussed at a conference between Mayor Low, Corporation Counsel Taylor, Chief Engineer Van Buren, the Controller, and City Works Commissioner Fleeman, and it was then resolved not to involve the city in the complications, which, these gentlemen believed, would certainly arise if an attempt were made to enter into a contract to have the work done at this time.

PROFILE OF B. & O. BRIDGE OVER SUSQUEHANNA RIVER.



B. & O. R. R. Bridge, Havre de Grace, Md. Location, Profile and Soundings.

BY COL. WM. M. PATTON, ENG., IN CHARGE.

After running several preliminary lines for the location of the Susquehanna bridge, of the B. & O. R. R. Co., Col. H. T Douglas, Chief Engineer of the Philadelphia branch, decided upon a line a short distance to the north of the bridge crossing of the Phila. Wilmington & Baltimore R. R. at a point where the river is divided into two channels by Watson's Island. A line further north still, though favorable as far as the cost of constructing the bridge was concerned, was rejected by reason of the unfavorable configuration of the ground in the shore approaches; requiring deep cutting, or tunnelling on the west side, or very high embankments, or equally deep cutting on the east. A line south of the present location would necessitate very high embankments on the west side, or a draw-span in the bridge at a low elevation, and deep cutting on the east shore.

The rapid dip of the rock southward, as indicated by the borings, was a more powerful factor still in the selection of the present location as the best under the combined circumstances. Full and careful borings were made by the author over the sites of the present piers, the results being shown on the accompanying diagram. In the west channel all previous borings indicated a generally level surface and only three borings were made at the site of each pier. But in the east channel such great and peculiar irregularities were discovered that a number of borings were made, and, as a result of the investigation, the piers in the east channel were moved westward. The general accuracy of these test borings has been proven by the work since done.

The borings were made by Mr. J. E. Robinson, of Baltimore. In making them a pipe 1½ in. diameter was first pressed a few feet into the mud, and inside of this was placed a ¾ in. pipe with a chisel-shaped end, having in it two small side apertures. This inner pipe was then connected by a hose to a small pump, and water was forced through it, issuing from the openings with great velocity, and cutting out the material and, when not too sandy, raising this to the surface in the space around the central pipe. In a sandy soil the water escaped laterally at the bottom of the tube, and, as no material was raised the downward progress was slow. Rock was indicated only by the inability to force the pipe farther. In other materials the hole made remained intact, and at depth of 90 ft. the pipe could be easily lifted and let fall again; the rebound and peculiar ring left no doubt when rock was reached.

In the east channel, at vertical intervals of 5 ft., samples of the material were brought to the surface by substituting for the chisel end of the ¾ in. pipe a brass tube, and then replacing the pipe in the hole; the fact that the hole remained perfect was indicated by this rod touching bottom at the same depth as had previously been attained. The brass tube was then pressed one foot into the bottom of the hole and the soil was brought up as it originally existed, showing the composition and stratification, if any, exactly, instead of exhibiting merely a mixture of the materials as in ordinary test borings. These samples were then forced into cylindrical glass tubes—lamp chimneys—and after the lapse of a year still retain their original moisture, the ends being sealed with a gum cloth.

Owing to the lay of the rock, as shown on diagrams "E" and "F," it was determined to level this rock by submarine blasting before

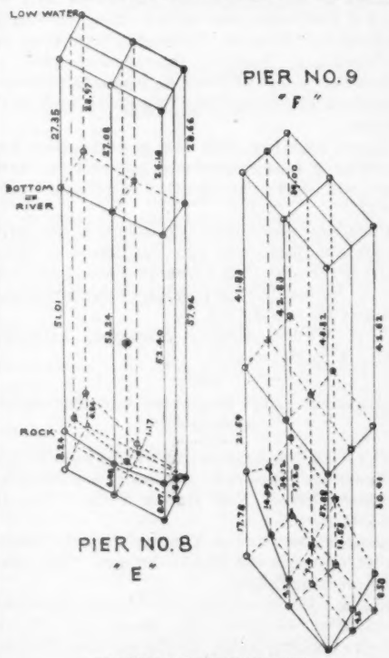


DIAGRAM OF SOUNDINGS.

attempting to sink the caissons. To this end a 4 in. pipe was sunk, by pumping, to the rock, and a heavy charge of dynamite was inserted, and fired by electricity. The result was unsatisfactory, and drilling into the rock was next attempted, but the rock was so hard that little progress could be made with a steel drill attached to 90 ft. of iron pipe and falling 6 to 8 ft. When the engineer was on the point of trying the diamond drill, orders came from headquarters to suspend these operations and blast the rock when it was reached by the caisson. The subsequent baring of the rock convinces the author that the original surface blasting would have resulted satisfactorily, as this rock has been found very irregular, with high points rising here and there, with almost vertical faces.

During the boring operations frequent pockets of gas were tapped, with a tension sufficient to support a water column rising in the pipe 11 ft. above the river surface. This gas was lighted on more than one occasion at the top of the pipe and burned for a considerable time. The presence of this accumulation of gas in the bottom material, of course, gave rise to considerable uneasiness, as there was the possibility of an explosion in the caisson during the sinking. But as the fact became apparent that when gas was tapped none was found in another hole only a few feet distant, it was evident that no large reservoir of gas was to be feared. It only existed in pockets, where it accumulated until the pressure was sufficient to overcome the surrounding resistance and escape to the surface in gas bubbles. No inconvenience was experienced in sinking the caissons, from this cause.

The material passed through varied so much from point to point as to require more than a passing notice. The accompanying profile shows depth of water and of solid material at the center of each pier, and the length of spans. At the center of Pier No. 2, we find 10.88 ft. of water and 56.55 ft. of sand and silt, in alternate layers, sometimes mixed, with the sand both in separate layers and as a component part of the mixture largely in excess. Below this formation was a mass of large and small boulders of an undetermined depth upon which the caisson rests. At the center of Pier No. 3, we find 12.17 ft. of water and 58.72 ft. of sand and silt corresponding in every respect with the strata at Pier No. 2, the caisson here likewise resting upon the boulder formation. At Pier No. 4, are 28.78 ft. of water and 32.26 ft. of a compact silt with little or no sand, and few boulders overlying the bed rock, which supports the caisson. In the east channel, Pier No. 8, has 28.95 ft. of water and 55.25 ft. bocompact silt with little or no sand and few veulders overlying the rock. The bed rock is 12ry irregular, differing by as much as 8 and bft. over limited areas, with, no gradual slope, u t abrupt changes of level. At Pier No. 9, we find 41.17 ft. of water and 32.59 ft. of compact silt with little or no sand, corresponding in every respect with the formation at Pier No. 8, excepting only that in the latter pier a thin layer of clean sharp sand was found immediately on the rock, and in Pier 9, layers of quicksand were found at varying heights, which gave considerable trouble. The rock at Pier No. 9, varied as much as 18 ft. in elevation under the caisson.

The solid material under Piers 4, 8 and 9 was composed of a compact, air and water tight mass with few or no boulders; under Piers 2 and 3 this formation was largely sand with a thick bed of boulders overlying the rock. At the first named piers we have the greatest depth of water and the most rapid current; at the last a comparatively small water depth and a slow current. As all this matter is of recent formation it seems that the deposit should have been in exactly the reverse order to that actually existing.

The length of bridge is as follows:—Between west abutment and Pier No. 1, 212 ft. iron viaduct; Piers No. 1 to No. 2, a 480 ft. deck span; Piers 2 to 3, a 480 ft. deck span; Piers 3 to 4, a 480 ft. deck span; Piers 4 to 5, a 520 ft. through span; Piers 5 to 6, a 480 ft. deck span; Piers 6 to 7, 1941.15 ft. of iron viaduct on masonry pedestals; Piers 7 to 8, a 380 ft. deck span; Piers 8 to 9, a 520 ft. deck span; Piers 9 to 10, a 380 ft. through span; Piers 10 to 11 a 200 ft. deck span, and between Piers No. 11 and the east abutment an iron viaduct of 242 ft. The total length of the structure is thus 6,315.15 ft. between abutments. When we take into consideration the great number of unusually long spans, the number and depth of the foundations, and the short time in which these foundations have been put in place, this bridge ranks among the most difficult and important structures in this country.

THE HISTORY AND STATISTICS OF AMERICAN WATER-WORKS.

BY J. JAMES R. CROES, M. AM. SOC. C. E. : M. INST. C. E.

(*Continued from page* 250 Vol. XII.)

DCC. ASHEVILLE, N. C.

Asheville, Buncombe Co., North Carolina, in lat., 35° 30′ N. long. 82° 25′ W., is on high ground 2,250 feet above sea level one mile from the French Broad River and two miles from the Swannanoa River, both of which flow through valleys 250 lower than the the town, which is surrounded by mountains from 300 to 4,500 feet higher.

The town was settled and incorporated in 1795. Waterworks were built by the city in 1883, after plans of A. Seversedge, C. E., and under superintendence of T. W. Patton, taking the supply from springs and streams about three miles from the city. The available watershed is 20 square miles. The water of each spring or stream is received in a brick chamber, from which it flows into the conduit which is of six inch earthenware pipe, and extends two and a half miles. At distances of 1,000 feet apart along this line, brick silt chambers are constructed, with blow-offs and overflow weirs. The pipe terminates in a reservoir excavated in rock and lined with cement, containing 500,000 gallons at 150 feet above the city. Distribution is by 1½ miles of cast iron pipe of 10 to 4 inches diameter with 5 fire hydrants. The number of taps is not stated; nor the daily consumption. The streams yield about 15,000 gallons a day. The works have cost $12,000. They are controlled by a Committee of the Trustees. T. W. Patton is the Secretary and Superintendent. The population of the city in 1880 was 2616.

DCCI, ATHENS, GA.

Athens, Clarke Co., Georgia, in lat. 33° 50′ N., long. 83° 30′ W., is on the Oconee River in a hilly district. It was settled about 1810. It is the seat of the University of Georgia and the State Agricultural College.

Waterworks were built by a private company in 1883, taking the supply from six springs issuing from sand rock, the water from which is pumped by two Blake pumps into an iron tower 18.5 feet in diameter, and 100 feet high. Distribution is by 7 miles of cast iron pipe, with 50 fire hydrants and 65 taps. There are 2 meters. Service pipes are of wrought iron. The town pays $60 per year for each hydrant. The daily consumption is 50,000 gallons. The works cost $75,000, which is the amount of the bonded debt at 5 per cent. Charles H. Leddie is the Chief Engineer, and M. H. Malon the Superintendent.

DCCII, BAINBRIDGE, N. Y.

Bainbridge, Chenango Co., New York, in lat. 42° 15′ N., long. 75° 45′ W., is on undulating ground in a rich agricultural region. Waterworks were built as a private enterprise in 1883 by J. W. Roberts, taking the supply from Artesian wells and springs, the water from which is pumped by a windmill. Distribution is by five miles of wrought iron pipe, with 20 fire hydrants. The number of taps and the consumption were not given. The village pays $300 a year for hydrants. The works cost $18,000. The bonded debt is $10,000 at 6 per cent. The yearly expense of maintenance is $400, and the revenue $1,400. The population in 1880 was 781.

WATER.

PHILADELPHIA Councils, on Dec. 23, passed an appropriation of $49,298, for the Water Department, including the increase of the salary of Chief Engineer Ludlow to $10,000 per *annum*.

AT Hiawatha, Kansas, while boring for an artesian well, a strong vein of salt water was struck. It is said to carry 20 per cent of saline matter. The great salt wells of New York and Michigan carry only from 13 to 16 per cent.—*Globe Democrat*.

HOUGHTON, Wis., has a system of water-works.

THE pump-works of B. G. McDonald of Dubuque, Io, shut down on Dec. 22.

THE *Lake Superior News* says that the Duluth waterworks have already saved from destruction property enough to pay for them twice over.

THE councils of Minneapolis, Minn., are discussing a suit against the city by the Minneapolis Mill Co., for $11,800, for power furnished for running the waterworks. The suit is for a surplus of power over the original contract.

THE water commissioners of Taunton, Mass., have determined to reprint their reports from the beginning. They will be furnished to any engineer or superintendent of water works who may apply for them to Wm. R. Billings, Clerk and Superintendent.

THE City Councils of Charleston, West Virginia, have granted to E. R. Davenport and associates a 30 year franchise for a water works. The works to be completed Jan 1, 1886; the city is to pay $50.00 each for hydrants, and have the privilege of buying the works after 20 years. Over 10 miles of Kalamine pipe will be used.

ACCORDING to a note from Francis S. Pecke, Engineer and Superintendent of the Jermyn, Pa., water-works, all work is now suspended for the season. There are 24 in. of frost in the ground. The main is laid and tested, in its entire length of 21,857 ft.; 3,600 ft. more of 4 in. pipe is to be laid in the spring.

AMONG the last inventions reported from Australia is a machine for producing rain storms. It is intended to force a rain supply from the clouds during a period of drought. The apparatus is in the form of a balloon with a charge of dynamite attached underneath it. The balloon is to be sent into the clouds, and when there the dynamite is to be fired by a wire connecting it with the earth. A trial of this novel contrivance is to be given upon the dry districts of New South Wales, and the result is looked forward to with interest by some of the residents of that colony.

BOSTON NEW HIGH SERVICE WORKS.—The City Council of Boston have passed an order authorizing a loan of $766,000 for the construction of new high service works in that city. The works to be built comprise a pumping station at Chestnut Hill Reservoir, containing two engines of five and ten million gallon capacity per twenty-four hours; a reservoir, 120 feet above the pumping station, holding 15,000,000 gallons, and four miles of force and supply mains. Between two and three years will be required for the completion of this work, which will be commenced during the coming year.

NEWS OF THE WEEK.

Contracting.

The National Tube Works, of McKeesport, Pa.,—are stated by the the general manager to have shut down only for repairs, as is usual at this season; they will be reopened early in January.

H. S. Hopkins & Co.—bridge builders of St. Louis have made an assignment to Joseph Dixon. The firm had just completed a $350,000 bridge for St. Louis. The liabilities are far in excess of the assets.

Duluth Items.—The total length of street improvements for the past year has been 12,318 feet or two and one-third miles and the cost has been $31,676. During the present year there have been built 26,830 feet of sidewalks or a fraction over five miles. Cost of same has been $6,604.

A Pipe Line.—YOUNGSTOWN (O.) capitalists are considering the advisability of building a pipe line from Butler County, Pennsylvania, to that city, to furnish manufacturing establishments, business houses and residences with natural gas a fuel.

Union Depot, Dayton Ohio.—THE Union Depot which the Cincinnati, Hamilton, and Dayton, the Panhandle and the Cleveland, Columbus, Cincinnati and Indianapolis Railways have agreed to build at Dayton, Ohio, will cost $1,000,000. Other roads centering there can be either renters or stockholders, as they may elect.

Japanese Labor.—OTTAWA, Ontario, Dec. 26.—Five hundred Japanese are being brought over from Japan to work on the railroads in course of construction in British Columbia to take the place of Chinamen. Within the past few weeks there has been a considerable exodus of Chinese to their own country. One steamer alone took several hundred last week.

Brooklyn Storm Sewers.—A communication was received last week by the Brooklyn Board of Alderman from Engineer Emory, representing the owners opposed to the plans prepared by the Board of City Works for the construction of the relief storm sewers. Plans were received from Mr. Emory, and the whole matter was referred to a special committee, with instructions to confer with City Works Commissioner Fleeman and Chief Engineer Van Buren, and report back what action it is necessary for the Common Council to take in the matter.

A 20,000,000 Contract.—BUENOS AYRES, Dec. 25, via Galveston.—According to the terms of the contract for the construction of a port here at a cost of $20,000,000, a second canal will be made in the roadstead. It will be 15 Kilometers long and 21 feet deep. A dock will also be constructed in front of the city. The contract has been signed, but has not as yet been made public.

New Work in St. Louis.—The Board of Public Improvements of St. Louis ordinances making additional appropriations for the reconstruction of Elm Street from Broadway to Seventh street; to partially improve Davis street between Broadway and Ivory avenue; to establish Branch Street Sewer District No. 19, and to construct sewers therein; to establish Grand Avenue Sewer district No. 18, and to construct sewers therein; to establish South Mill Creek Sewer District No. 85, and to construct sewers therein; and to establish Joab Street Sewer District No. 8, and to establish sewers therein.

Duluth Elevators.—DULUTH, MINN., Dec. 23.—At a meeting of the stockholders of the Lake Superior elevator company, held in this city yesterday, it was definitely decided to build another elevator at Duluth for the business of the coming year, with a capacity of 1,500,000 bushels, and it is understood that the Union Improvement and Elevator company will also build another 1,000,000 bushels capacity. The erection of these elevators has been rendered absolutely necessary by the proportions which the grain trade at Duluth has now assumed, and by reason of the fact that trade is increasing so rapidly that large transactions now take place on change daily and many new members have recently joined the Board of Trade. That Duluth is rapidly coming to the front as a trading wheat market is shown by the fact that during the past season she shipped very nearly, if not quite as much, wheat as Chicago, and that she already has in store for winter storage 4,500,000 bushels, and will have 6,000,000 bushels in store by next spring. The capacity of Duluth elevators, when the new houses are completed, will be 8,7000,000.

Railroads, Bridges and Canals.

Milwaukee, Lake Shore & Western R. R.—Twenty miles have been graded east from Ashland for the Milwaukee, Lake Shore and Western, while the force working west have crossed the Montreal River.

The North Pacific R. R.—The Northern Pacific has only six miles more track to lay on its extension from Superior to Bayfield. It is thought trains will be running before January 1.

For best Section of Road.—The Panhandle Inspectors have awarded to Supervisor McNamee, the first prize for best section of track, from Bradford Junctfon to Richmond, Ind.; Supervisor Burrgess has the second prize, for track between Cambridge and Indianapolis.

The Lachine Bridge.—MONTREAL, Dec. 25.—General Manager Van Horne, of the Canada Pacific Railway says that the arrangements for the Lachine bridge are not far enough advanced to talk of a contract. Funds are wanting for this and other parts of the Canada Pacific Road, and until the bonds of the Ontario and Quebec Railway are floated, there is no hope for the Lachine bridge or a loop line from Smith's Falls to Montreal.

The Panama Canal.—PANAMA, Dec. 16.—It is reported here that when the time of Mr. Dingler's contract with the Canal Company expires he will withdraw from the work of construction. Lieut. Napoleon Bonaparte Wyse is spoken of as Mr. Dingler's successor.

Among the recent deaths by yellow fever is that of Mr. Haubert of the Canal Compeny. Mr. Haubert was the eleventh victim of yellow fever out of a party of thirty-three new comers that landed on the Isthmus with Mr. Dingler on Oct. 28, 1883.

The Canal Company is advertising in Jamaica for 40,000 laborers. Mr. Deuillot, a cousin of M. de Lesseps, is now in Mexico trying to hire 15,000 Mexican Indians to come to the Isthmus.

Mexican Central.—BOSTON, Mass., Dec. 22.—In a circular to the stockholders issued by the Mexican Central Railroad Directors, a proposal is made whereby the deficiency of about $3,000,000 may be met, one feature of the plan being the issue of debentures of $1,000, bearing 10 per cent. interest, dated Jan. 1, 1885, and payable April, 1, 1895. The proposal is as follows: For $900 in cash, payable in 20 per cent. installments, the company will deliver seven shares of capital stock at its par value, $100 per share, $200 in its 3 per cent. income bonds, (scrip being given for fractions,) and $1,000 in its 10 per cent. debentures above described. The Directors expect to raise $2,700,000,000 under this circular, and if their expectations are met all the floating indebtedness will be paid and the company will have in its treasury over $500,000 cash, $3,000,000 first mortgage bonds, $200,000 income bonds, $1,000,000 stock, and $4,000,000 subsidy certificates.

A New Canadian R. R.—Application will be made to the Canadian Parliament, by the Cleveland Steam Nav-

igation Co., of Detroit, for a charter to build a railway from some port at or near Windsor to some port on Lake Erie.

The New London Bridge.—The N. Y. Providence & Boston R. R., and the New York & New Haven R. R., are still fighting about dividing the cost of building the above bridge across the Thames River; the amount, including land damages, is $1,500,000. For the present the project is abandoned, and will hardly be resurrected until the first named road is ready to foot the total bill.

Air Tubes Instead of Bell Cord.—The Pennsylvania Railroad Company, after an experiment covering nearly eight months with the new patent of communication between passenger cars and the locomotive by means of air tubes instead of bell cord, has finally adopted the system permanently. It is being used with satisfaction on many of the trains.

A New York Cable Railway Co.—Thos. C. Platt and others entered a certificate of incorporation, on Dec. 16, for the New York, New Jersey and Pennsylvania Cable Co. It has for its professed object the propelling of railway cars by the inventions of Almerin H. Lighthall. Capital stock $5,000,000. The real object is said to be the operation of cable railways in New York City.

Chesapeake & Nashville R. R.—R. L. Williams, Assistant Engineer reports that parties are running over the line partially completed between Gallatin and Scottsville, Ky. Parties are actively securing right-of-way between Gallatin and Nashville. The money is raised to make the surveys between Gallatin and Carthage, Tenn.

No more Pay-cars.—It is reported that both the West Shore and Erie Railway Companies are about to adopt a new system in paying their old employes which will entirely do away with pay masters and pay cars, thus saving a large item of expense. The plan is to send the vouchers of each employe from the general office monthly to the station agents, from whom checks will be received by each man.

New Bridge in the Mississippi Valley.—VICKSBURG, MISS., December 21.—The new iron bridge on the Louisville, New Orleans and Texas Railroad over Big Black River, about twenty miles below this city, was completed yesterday. It was tested to-day, and the first train will pass over to-night. The bridge is a fine structure, 300 feet long. It cost $6,000, and was built by the Phœnix Bridge Co., of Phœnixville, Pa.

A $2,000,000 Decrease.—PHILADELPHIA, December 24.—The statement of business of all the lines of the Pennsylvania Railroad Company east of Pittsburg and Erie, for eleven months of 1884, compared with the same period of 1883, shows a decrease in net earnings of $1,209,202. All the lines west of Pittsburg and Erie for eleven months of 1884 show a decrease, compared with the same period of 1883 of $1,946,808.

New Enterprises.—MASSACHUSETTS.—A street railway is projected to connect Brockton with North Easton. It will be 6½ miles long. Geo. E. and Rufus P. Keith, of Brockton, are leading stockholders.

GEORGIA.—The Rome Street Railroad Company, Rome, Ga., has been incorporated.

ALABAMA.—A street railroad will be built at Montgomery. T. Gardner Foster, of Montgomery, is interested in the project.

TEXAS.—The Queen City Railroad Company has been organized at Fort Worth, Texas, to build a street railroad. The Brenham Street Railway Company has been chartered at Brenham.

INDIANA.—The South Bend & Mishawaka Street Railway Company, which has a capital of $100,000, has filed articles of incorporation with the Secretary of State The directors of the company are Edward B. Dikeman Perley H. Brown, Jeremiah W. Boynton, J. H. Knight and John Lyons.

THE Riverdale & Lake Michigan Railroad company has filed articles of association with the Secretary of State. This road is to a standard gauge from Riverdale to Hartford, a distance of 116 miles. The incorporators of the above named railroad will also build the Ohio & Central Michigan railroad, to run from Coldwater south to the State line.

The Keystone Bridge Works.—PITTSBURG, Penn., Dec. 29.—The sudden suspension of the Keystone Bridge Works, on Saturday, was fully explained this morning by a statement which has been verified, that serious differences of opinion existed between the stockholders of the corporation. It is known that President Gottlieb and Secretary and Treasurer Strobel were both opposed to the proposed reduction, and resigned, and on Saturday A. B. Griffin, of Chicago, was elected President, and J. H. Springer, of this city, General Superintendent. The works, as now organized, will resume in a week if the workmen accept the reduction ordered. The works have contracts for nearly a year. Including the Baltimore and Ohio Railroad Bridge over the Susquehanna River, a bridge for the Louisville and Nashville Road, and a pivot bridge for the Wabash Road, the contracts for which were made before a serious depression in business occurred,

Market Report of Engineering Materials.

New York, January 3, 1885.

NOTE.—The following Market Report gives wholesale prices on the New York Market unless otherwise stated. It is intended as a general guide to the estimating engineer, and both the range of material and the market location will be extended as rapidly as possible. We give it with this caution, that, as is well understood in business transactions, the amount of bill, distance from market centre and conditions of payment will have a material influence on the final paying prices.

IRON.		
STRUCTURAL IRON.		
Angles	2.3c. @	2.6c.
Bridge plate		
Tee	2.8c. @	3c.
Beams and channels	3.8c.	
Tank	2.2c. @	2.3c.
Shell	2¾c.	
Steel plates, Tank	3c. @	3½c.
WROUGHT-IRON PIPE.		
Butt welded, black ..... Discount	45 per cent.	
" " galvanized ..... "	35 "	
Lap welded black ..... "	65 "	
" " Galvanized ..... "	50 "	
Boiler tubes ..... "		
RAILS.		
Steel (large lots at mill)	$27 @ 28	
Old rails	16.50 @ 17	
Old steel rails	16 @ 17	
R. R. spikes		2c.
R. R. splice-plates	1.65c.@	1.75c.
Barb-wire fencing, galvanized		5c.
" " painted		4c.
Corrugated iron		
BRICK.		
(Cargoes afloat)		
Haverstraw 1st, ... per M.	$6.12½ @	6.50
" 2nd ..... "	5.75 @	6.00
Fishkill	5.50 @	5.75
Up-River	5.00 @	5.50
Jerseys	4.50 @	5.50
Long Island	5.50 @	5.75
" pale	3.00 @	3.25
FRONTS.		
Croton red	14.00	
" dark	14.00	
" brown	13.00	
Philadelphia pressed	23.00 @	25.00
Trenton "	22.00 @	23.00
Baltimore "	35.00 @	37.00
Buff "	33.00 @	35.00
Enameled English	65.00 @	130.00
" American	85.00 @	120.00
Fire brick	25.00 @	35.00
CEMENT.		
PORTLAND.		
Robins & Co., Extra English 425 lbs	2.75 @	2.90
R. B. & S. English 400 lbs	2.65 @	2.80
Burham " "	2.50 @	2.60
Rochester Castle " "	2.50 @	2.60
J. B. White & Bro. " "	2.50 @	2.60
Other brands, " "	2.40 @	2.50
Keene's fine " "	9.50 @	9.75
" course " "	5.25 @	5.50
Roman	2.75 @	3.50
Dyckerhoff, German 400 lbs	2.60 @	2.65
Star, " "	2.60 @	2.65
Alsen, " "	2.55 @	2.60
Hanover " "	2.40 @	2.50
Other brands, " "	2.35 @	2.40
Saylor's American	2.15 @	2.50
Rosendale cements	0.90 @	1.00
LIME.		
Rockland common per bbl	1.00	
" finishing	1.20	
Glensfalls, common	.85	
" pointing	1.05 @	1.10
Kingston, ground	0.95	
STONE.		
Cargo rates at New York.		
Amherst freestone, No. 1 per cub. ft	1.00	
" " No. 2 "	0.85 @	0.95
" " light drab "	0.80 @	0.95
Berlin " in rough "	0.75 @	1.00
Berea " "	0.75 @	1.00
Brownstone, Portland, Ct. "	1.00	
" Belleville, N. J. "	0.80 @	1.25
Granite, rough	0.60 @	1.25
Common building stone per load	2.00 @	3.00
Base stone, from 2½ to 6 ft. lengths, per lin. ft.	0.40 @	3.00
SLATE.		
Purple roofing per square	7.00 @	8.00
Green "	7.00 @	8.00
Red "	15.00	
Black Penna. (at New York) "	4.90 @	5.00
LUMBER.		
PINE, Common box per M.	16.00 @	18.00
Good "	55.00 @	60.00
Tally plank, 1¼ in each.	.30 @	.60
Tally boards, dressed "	.28 @	.35
SPRUCE, Boards dressed "	.25 @	.28
Plank, 1¼ in "	.28 @	.30
" 2 in. "	.38 @	.40
" 2 in. dressed "	.43 @	.45
Timber per M.	20.00 @	20.00
HEMLOCK, Boards each.	.18 @	.20
Joist, 2½ × 4 to 4 × 6 in	.17 @	.44
OAK per M.	55.00 @	65.00
CYPRESS 1, 1¼, 2 and 2½ in "	35.00 @	40.00
YELLOW PINE, Girders "	26.00 @	35.00
Dressed flooring "	30.00 @	40.00
SHINGLES, Extra shaved pine, 18 in. "		
" sawed " 18 in. "	5.75 @	6.00
LATH, Cargo rate	2.50 @	2.60
PAINT.		
Lead, white, American dry per lb	.05½ @	.06
" " in oil pure "	.06¾ @	.06¾
English, B. B. in oil "	.06½ @	.06¾
Red, American "	.05½ @	.05½
Litharge "	.05 @	.05¼
Venetian red, American "	.01 @	.01¼
Indian red "	.05 @	.09
Vermillion, American lead "	.11 @	.11½
Paris green "	.16½ @	.20
Umber, Amer. raw and powdered "	.01¼ @	.01½
Drop black, Amer. "	.09 @	.10
" " "	.09 @	.11½
Chrome green "	.07 @	.13
Oxide zinc, American "	.03¾ @	.04
" " French "	.06¾ @	.08